# MEMOIRS

OF

# THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XXI, PART 2.

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Geol.

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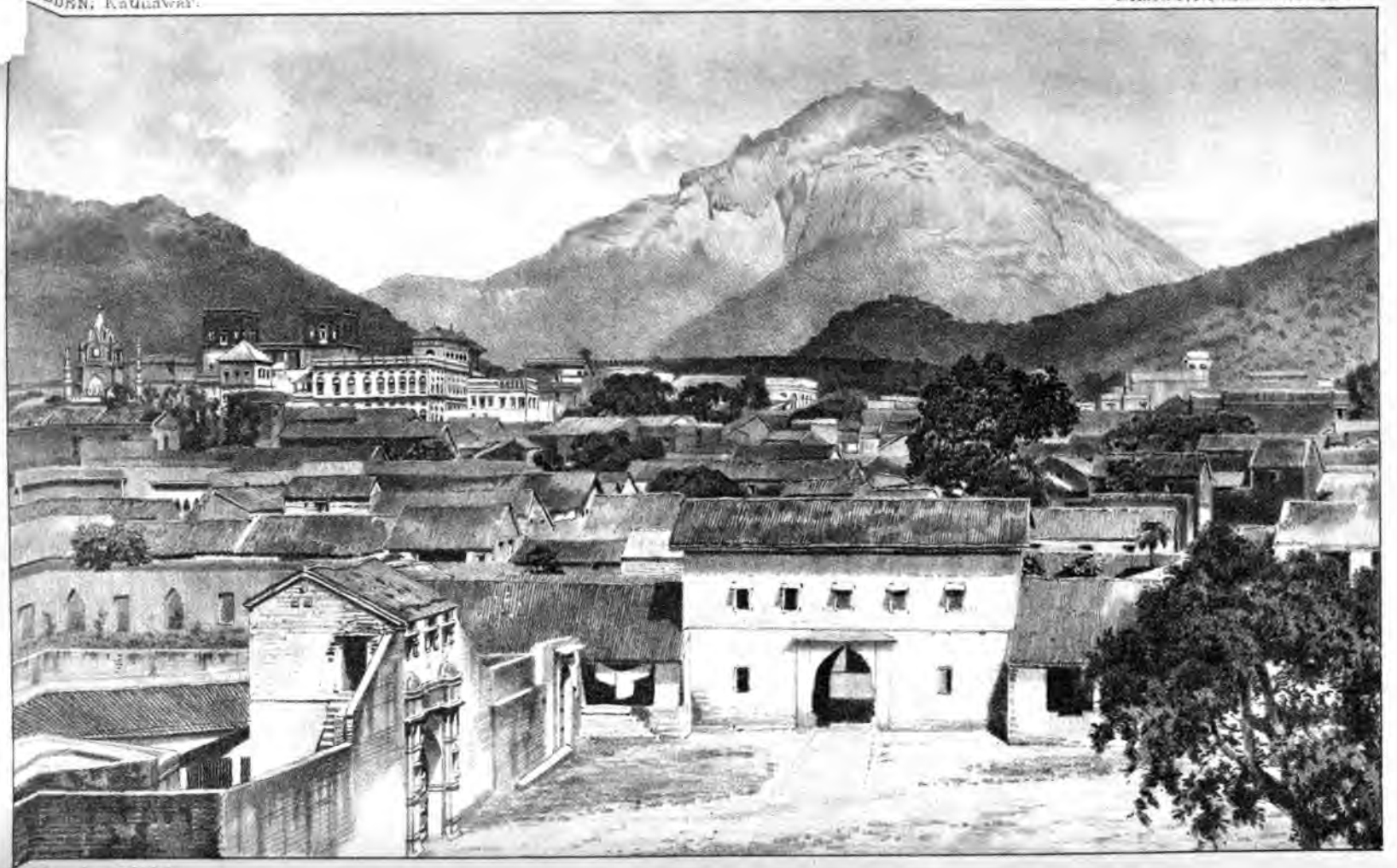

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# PREFACE.

It is desirable, or indeed needful, to indicate some points of correlation in the following memoir that are not quite up to date of our information. Only the paged proofs of the paper came into my hands on my return from Europe, and after Mr. Fedden had himself gone on furlough, so I could only introduce small verbal corrections.

In the table of formations on page 6, Mr. Fedden affiliates his Trappean-grits of Káthiáwár to the Infra-trappean-grits of Cutch, and his Wadhwán-sandstones of Káthiáwár to the Infra-trappeans of India. This latter term has always been restricted as synonymous with the Lameta group (Manual, page xiv, *et passim*), and although Mr. Blanford in his cursory survey of the Narbada region (in 1864) suggested that the cretaceous beds of Bág (Bagh) were probably on the same horizon as the Lameta group, the two have never been confounded, the latter being fresh-water deposits and the former marine. Mr. Bose in his recent detailed survey of the Bág region has further established the separation by tracing the distinctive Lameta beds overlying the marine beds of Bág. Now, it is plain from Mr. Fedden's description of the Wadhwán-sandstones (page 12 *et seq.*) that their affinity is with the Bág beds and not with the Infra-trappeans, or Lametas; the fossil contents, the stratigraphical relation of decided erosion-unconformity to the overlying trap, and the close connection with the underlying Umia sandstone, can

scarcely leave a doubt upon this point. It is only right to mention that Mr. Fedden seems not to have had access to Mr. Bose's memoir, the publication of which had been much delayed for the preparation of one of the maps; but the position was sufficiently clear from previous publications.

Although these main facts would seem to settle the correlation, there are some noteworthy discrepancies in details. The Wadhwán group is mostly sandstone, whereas the Bág beds are principally limestone. The cherty bands at top would recall a Lameta character of the Bág area. But the chief point of contrast with Bág beds is the association of trap rock with the upper beds of the Wadhwán group. This is implied in several places and is directly affirmed on page 18, notwithstanding the previously described deep erosion-unconformity with the trap. It may be that some of these cases are only contact-effects; and that in others, beds have been taken as of the Wadhwán group which should have been placed in the succeeding Trappean-grits.

Some vernacular words are quite needlessly introduced in Mr. Fedden's text. Foreign readers may like to know that *nala* means a stream, or rather its channel; *talao* is a tank; and *talaori*, I imagine, a little tank, or perhaps a pond.

The description of the sequence of formations in Káthiáwár seems to me to necessitate a correction of the sequence in the lower Narbada area as described by Mr. Bose in the first part of this volume, regarding the affiliation of his Nimár-sandstone, ranked by him as lower-cretaceous. The probabilities were already decidedly against this view (see Manual, page 221), and he has shown no sufficient ground for disregarding them. In the original cursory survey of that ground by Mr.

Blanford (*supra*, Vol. VI, part 3), this Nimár-sandstone (excepting only the oyster-bed at top) was included with the rock described by Mr. Bose as Gondwána sandstone, both being classed with the Bág-beds as cretaceous. The probabilities aforesaid were not then in view. In 1875 (Records, G. S. I., VII, page 73) a strong unconformity of the Bág marine fossiliferous beds to the underlying sandstones of Ghatia at the eastern end of the area were brought to notice, and the decided affinity of these latter with the upper Gondwána pointed out. After the correlation by Dr. Feistmantel of the flora of the jurassic Umia group of Cutch with that of the topmost group (Jabalpur) of the Gondwána system in the Sátpura region, the absence of any rock in Cutch between the Umia group and the thin zone of marine cretaceous deposits, to represent the mass of supposed cretaceous sandstone in the lower Narbada region, was noteworthy as confirming the view of these latter being really of Gondwána (Umia) age. From Mr. Bose's own description the same view is further confirmed. He did not, it is true, detect any other case of unconformity of the oyster-bed with the underlying sandstone, but the distribution of the two is conspicuously distinct, the latter occurring far and wide apart from the marine beds, while the oyster-bed is only noticed with the other marine beds, and is described as passing into them (*l. c.*, page 33). Moreover, the Nimár-sandstone is described as having a strong resemblance to the Gondwána beds of Ghatia, and as containing the same fossil drift-wood (pp. 32-35). And now the Káthiáwár evidence comes in: in comparative proximity to the lower Narbada region, and directly in extension of it, we find a small group fairly representing the marine cretaceous beds of Bág and resting directly on the

Umia. There seems to me very little room for doubt that the Nimár-sandstone is of upper Gondwána age, and therefore jurassic, not cretaceous. The probabilities of the case were duly pointed out to Mr. Bose, but as he had been over the ground and I had not, I did not insist. He seems to have been fascinated with the idea of making up a symmetrical cretaceous system—a fatal proclivity that is apparent in other parts of his memoir.

H. B. MEDLICOTT,
*Superintendent, Geological Survey.*

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# MEMOIRS

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## The Geology of the Káthiáwár Peninsula in Guzerat, *by* Francis Fedden, A.R.S.M., F.G.S., *Geological Survey of India.* (*With a plate and a map.*)

### CHAPTER I.

#### INTRODUCTORY.

*Topographical.*—The province of Káthiáwár (Kattywar)[1] occupies the peninsula between the Gulfs of Cutch and of Cambay in the Bombay Presidency. On the north it is bounded by the Gulf and Ran[2] of Cutch; while the extensive southern shore is washed by the Arabian sea. The extreme length of the peninsula is about 220 miles; its greatest breadth about 165 miles; and its area 22,000 square miles exclusive of any part of the Ran.

The peninsula has an irregularly shaped outline, somewhat resembling on a small scale that of a hatchet-head. Generally speaking, the surface is undulating with low ill-defined ranges of hills. The central

[1] *Surâshtra* was the old name for this portion of Guzerat. It was known to the Moguls as '*Soráth*', and to the Greeks under the name of Σαυραστρήνη.

[2] Sometimes spelled 'Runn' and 'Rann,' occasionally 'Erun;' the word signifies a waste tract dangerous to travel.

portion of the country is the most elevated, while the surrounding land, subsiding into extensive plains, has a general easy slope towards the margin of the peninsula.

The shores are, for the most part, very slightly raised above the level of the sea: along the south-east coast there are low cliffs here and there, formed chiefly of sub-recent rock; while the south-west coast presents a remarkably straight and unbroken line, fringed by low parallel ridges of consolidated shore deposits and sandhills. The northern and eastern confines of the province are the least conspicuous; the rock plains merging, on the one hand, into the shallow Gulf of Cutch without definite coast line, and on the other, into the great stretch of alluvium towards Ahmedabad. Sandhills are prevalent along a portion of the margin of the Ran.

Hills.

With the exception of the Tángha and Mándháv hills in the west of Jhaláwár, and some unimportant elevations in Hallár, the northern portion of the province is flat; but in the southern part beyond the central tract of broken hilly country, in which are some great mural scarps, there are several prominent ranges and detached hills. Of these, the Junágarh group is the most conspicuous, with its lofty peak, Gírnár, rising to a height of 3,666 feet above sea-level. A short distance to the south-east of this group begins the 'Gir' (or Gar) range, a hilly jungle tract, which stretches away for 20 or 30 miles in an easterly direction. A rather sharp anticlinal fold in the rocks south of Bhávnagar (Bhownagar of the Map) has been named the Khokhra range. Shetrúnja,[1] or the sacred hill of Pálitána, lies 18 miles to the west of the Khokhra range.

Returning westward, we have the Barda[2] group, an assemblage of hills, covering an area of about 70 square miles, to the north-east of Porbandar. Osham is also a conspicuous hill, rising abruptly from the plains west of Junágarh.

Several of these hills are volcanic, or at least had an eruptive origin, as will be demonstrated from their structure in a later chapter. Another

[1] Often written 'Satrúnja.'

[2] More correctly 'Baradá,' as in Hunter's Gazetteer.

feature to be noted about the hills, considering their inland position, is that in many instances their seaward sides are the steeper and often precipitous, while the other sides tail off more gradually, or die down into broken ground. There is a remarkable feature in the topography of the Gohelwár division of the south-eastern part of the province; namely, the occurrence of numerous narrow ridges running for many miles across the country, like long embankments, or at times resembling great ruined walls. These often continue parallel to each other for long distances, while others cross them nearly at right angles; and they frequently attain a height of 200 or 300 feet above the plain. The same feature is noticeable, though less conspicuously, in other parts of the country.

Rivers.

The drainage of the province, as might be inferred from its configuration, is distributed on all sides over a great number of small river areas. Of these the following are the more important. In the northern division we have the Áji passing by Rájkot; the Machu by Wánkáner, Morvi, and Mália; and the Bhámban, which discharges into the 'Ran' near Tikar. In the south-west, one of the Bhádars[1] passing Jetpur and Kúntiyána to the sea at Navi-Bandar, runs a course of 120 miles: this is the largest river in the peninsula, and it is navigable for small boats up to Kúntiyána during the months of July, August, and September. The Ojat drains the Junágarh hills on every side, and diffuses its waters over the alluvial flats near the coast below Navi-Bandar.

In the eastern division: we have the two Bhogáwas, one passing by Múli and Wadhwán, the other by Limbri; the second Bhádar passing by Ránpur and Dhándúka; the Khalubhar, which is tidal at Bhávnagar; and the Shetrúnja passing Talája and falling into the Gulf of Cambay near Gopnáth Point. With the exception of the Bhádar first mentioned, these rivers can hardly be described as perennial.

Rainfall.

Though Káthiáwár is within the influence of the south-west monsoon, the rainfall is usually very light. The average annual fall at Rájkot is stated to be under 28

[1] There being two rivers having this name, as well as two Bhogáwas, it is necessary so to distinguish them.

inches. But the amount varies rather considerably in different parts of the province: at Gogha (Gogo) on the east coast, the rainfall is seldom more than 20 and often as little as 12 inches. The register at Bhávnagar for ten years prior to 1878 shows an average of 26·35 inches per annum.

Soil and vegetable products.

The province is agriculturally wealthy; the soil, though not of extraordinary fertility, being generally of fair quality and amply watered. The principal vegetable products of the country are cotton[1] 'kapas' (*Gossypium herbaceum*), 'bajri' (*Penicillaria spicata*), and 'juwár' (*Sorghum vulgare*), and in some parts sugar-cane 'serdi' (*Saccharum officinarum*), wheat 'ghau' (*Triticum æstivum*), rice 'dangar' (*Oryza sativa*), gram 'chana' (*Cicer arietinum*), 'math' (*Phaseolus aconitifolius*), and oil seed 'tal' (*Sesamum indicum*).

Animals.

The wild animals include the lion (now found in the Gir range only, but formerly in the Barda hills also), panther, cheetah, nylgai, sámbar, antelope, gazelle, hog, hyena, wolf, jackal, lynx, wild cat, fox, porcupine, and other smaller vermin; while the crocodile is common in many of the streams.

Of birds, wild duck and game birds are plentiful in those parts of the country suited to them, together with numerous storks, cranes, and pelicans. The great Indian bustard (*Eupodotis edwardsi*, Gray) is occasionally met with on the plains.

*Previous geological writers.*—There is scarcely anything authentic on record regarding the geology of the peninsula itself: the little island of Piram (Perim), off the east coast, has however frequently received attention since the discovery in 1836 of quantities of fossil bones and wood on the reef surrounding the islet. The earliest announcement of this discovery is given in a letter dated April 1836, by Baron Carl von Hügel to the Secretary of the Asiatic Society of Bengal, and published in the May number of the Society's Journal for that year. Baron Hügel states that Dr. Lush, who showed the first specimens to him, has the merit of the discovery. At

Hügel.

[1] The cotton annually exported supplies one-sixth of the total amount of cotton shipped from Bombay to foreign countries.

the same time, and in the same Journal, was published a description of the islet by Lieutenant Fulljames. In the December number of the volume, there are some 'geological notes' by Dr. Lush, which relate in part to the islet of Piram and neighbouring coast.

Falconer.

In 1845 Dr. Falconer read a paper before the British Association on some Piram fossils collected by Fulljames; and later in the same year he published, in the Quarterly Journal of the Geological Society of London, a fuller description of the Piram fossils, together with extracts from the papers above mentioned regarding the structure of the island and opposite coast.

Theobald.

In the year 1857, Mr. Theobald, late of the Geological Survey of India, examined a portion of the country bordering the southern and eastern coasts, but his report was not published, and therefore need not be taken in review. But since it was the authority for the statement in the 'Manual of the Geology of India' (p. 342), that nummulitic limestone occurs in Káthiáwár, I may here mention that no such rock has been met with by me in the province. None of the tertiary rocks exposed can be of earlier age than miocene.

It has been stated from time to time, in sundry reports and gazetteers, that the Girnár of the Junágarh hills is a mass of granite; this too is erroneous: the Girnár mountain is composed mostly of diorite (a black and white crystalline granular rock of hornblende and felspar) and of mica diorite. There is no granite in any part of the country.

Blanford.

In February 1863, Mr. W. T. Blanford made a visit to the island of Piram, and published a note on the subject at the end of his memoir[1] on the geology of Western India (issued, January 1869). The chief object of his visit being "for the purpose of endeavouring to ascertain if the beds there existing, which from their mammalian fauna are considered of miocene age by Falconer, presented any marked resemblance to the upper beds in the Oomrawattee, Keen, and Taptee rivers."

[1] Memoirs, Geol. Sur. India, Vol. VI, part 3, p. 211.

## CHAPTER II.

### GEOLOGY.

*Geological formations.*—The following table comprises all the formations occurring within the province. Several of them are but poorly represented, both in thickness and extent. The trappean series assumes by far the most prominent position, as it occupies fully two-thirds of the total area of the Káthiáwár peninsula, and its maximum thickness can scarcely be less than 3,500 feet. The tertiary rocks form a fringe to the trap along the southern limit of its area, but they are greatly obscured by the later sub-recent deposits and alluviums.

Table of geological formations occurring in Káthiáwár, in descending order:—

| Formations. | Approximate geological position. |
|---|---|
| *Alluvium.* (Sand dunes, tidal flats, freshwater alluvium, 'ran' clays, raised beaches and miliolite.) | RECENT AND SUB-RECENT. |
| *Dwárka beds.* | ? HIGHER TERTIARY, or POST-PLIOCENE. |
| *Gáj beds.* | UPPER MIOCENE.—(Lower Manchar in part, and Gáj of Sind.) |
| *Lateritic rocks.* | ? LOWER EOCENE.—(Sub-nummulitic (*Wynne*) of Cutch, and ? High-level laterite of the Deccan.) |
| *Traps.* | CRETACEO-EOCENE.—(Deccan traps.) |
| *Trappean grits.* | ? CRETACEOUS.—(Infra-Trappean grits (*Wynne*) of Cutch.) |
| *Wadhwán sandstones.* | ? CRETACEOUS.—(Infra-Trappeans of India.) |
| *Umia beds.* | JURASSIC.—(Upper Gondwána.) |

*Umia beds.*—The only representative in Káthiáwár of the great jurassic system is a group of sandstones exposed in the northern part of the province, and occupying an area of about one thousand square miles. These sandstones have been determined, by their mineral character and

by certain plant impressions, to belong to the Umia[1] group of Cutch. They do not represent the entire group, nor can their precise horizon in the group be stated; though—from the absence of the Cutch lower marine beds, and the identity of some of the plants with the Jabalpur group of the Gondwána system in the Central Provinces—the probabilities are that the Káthiáwár beds represent the upper division chiefly, and perhaps a higher development of the group than is seen in Cutch.

Sandstones and shales.

The sandstones are mostly open, imperfectly cemented, and unevenly stratified with coarse and gritty, or even conglomeratic, runs and layers. There are, however, some thick beds of fine texture among them, and a few subordinate bands of shale. Oblique lamination is very prevalent. Owing to the rocks in this field being so little disturbed from their original horizontality, and the country being generally flat, a natural section showing any great succession of beds cannot be expected. Thus, it is difficult to give an estimate of the thickness of the group; moreover, denudation has affected the surface, and the base is nowhere laid bare. There may be an aggregate thickness of about 1,500 feet exposed; and this, perhaps, exceeds the actual amount, for, in some parts of the field, similar rock spreads over large areas.

Thickness.

In the following details, the relative positions of certain zones in the group are given as nearly as can be.

Harsh and conglomeratic beds.

The hills with rugged outline, occupying the more elevated parts of the central portion of the field, are formed of harsh sandstone, ferruginously stained to dark purple or black. The rock is very coarse in parts, and even conglomeratic with small pebbles of white quartz imbedded in a dark ferruginous matrix: occasionally it is free from iron, or faintly mottled red and white. In many places it is so compact as to resemble quartzite. In this state it is

[1] The term 'Umia' was instituted by the late Dr. Stoliczka to denote a great thickness of beds succeeding the 'Kátrol group' in the jurassic series of Cutch. With the exception of the plant-bearing strata, which are scarce, they are for the most part unfossiliferous, and probably of fresh-water origin: marine fossils, however, are said to occur in a band towards the base, and again in a bed near the top of the group. None of these marine fossils have been detected in the present field.

quarried for 'quernstones,' or handmills, for grinding corn. This harsh sandstone, with conglomerate, I consider one of the uppermost exposed members of the group.

Softer sandstones of the plains.

The rock below it—forming the base of the hills, and occupying the open country and wide-spreading plains—consists of yellow, and pale-coloured, soft sandstones, variable in texture, often speckled with kaolin, or decomposed felspar, and sometimes warted with calcareous concretions. The coarser parts frequently change to grit, and conglomeratic bands of cemented pebbles are met with. The bedding of this rock is ill-defined, but cross lamination is very prevalent and strongly marked, especially among the finer deposits. Wherever large surfaces of this sandstone are exposed and sufficiently clear, excellent examples of a kind of 'ripple mark,' or current wave, may be often seen, showing that the material of the rock was pushed along, when deposited by swiftly flowing shallow water. The oblique lamination presents large semicircular, concentric wavelets. A good illustration of this occurs in the broad flood-way of the stream course on the west side of the town of Thán. Here two distinct sets of wavelets can be traced, the one almost at right angles to the other.

The light-coloured soft sandstone is one of the most prevalent rocks in the field, but it is rarely sufficiently coherent to bear trimming to the size of a cabinet specimen,—a blow from the hammer shattering it to sand. The surface only becomes somewhat more compacted by percolation of lime, after long exposure to meteoric influences. This member of the group attains a considerable thickness, which cannot be far short of 500 feet in the hills situated between Chotila and Thán.

Ironstone band.

About the middle of the soft sandstone beds, or somewhat lower, is an ironstone band, varying in different parts of the field from a red clay-shale with layers of earthy red hæmatite, or bole, to a brick-red highly ferruginous sandstone.

Near Wánkáner, and again at Mátel, 9 miles to the northward, the band is strongly developed in red earthy and arenaceous beds. At Deosar, 6 miles north-by-east of Chotila, it is a purple-red shaly band

of about 12 to 15 feet in thickness, passing down into ferruginous sandstone. It is traceable for some distance along the scarp of the hills to the westward, but appears to thin off to the east: at Chorvira, in the latter direction, it is only a very few feet in thickness; and it is succeeded, above and below, by the light-coloured soft sandstone.

In former days this ferruginous band was worked, and the ore smelted for iron in many places, notably at the village of Kántrori, 8 miles west of Sara. Scarcity of fuel and the cheapness of the imported metal have caused this industry to die out.

Among the sandstones below the ferruginous zone, there occurs a band of thinly-laminated fine shaly sandstone, or arenaceous shale, associated with dark argillaceous and carbonaceous shale, the latter containing numerous impressions, mostly fragmentary, of fossil plants, leaves, seeds, &c. The fossils were obtained from two localities—one near the village of Songadh 2½ miles N.N.E. of Thán, and the other three-quarters of a mile north-west of Thán. There is a very limited exposure of the beds at either place. The specimens from Songadh comprise, on the authority of Dr. Feistmantel the following:—

Plant shales.

FILICES.

*Pecopteris*, sp.
*Tæniopteris*, sp.

CYCADEACEÆ.

*Podozamites lanceolatus.*

CONIFERÆ.

*Echinostrobus* (*Thuites*) *expansus.*

Of these plants, the last named is common to both the Jabalpur and the Umia (Cutch) groups; while the *Podozamites* was known in the former group only.

The second locality (north-west of Thán) proved the richer, and the specimens obtained therefrom have been named and discussed by Dr. Feistmantel in a short paper published in 1880.[1]

[1] Records, Geol. Sur. India, Vol. XIII, p. 62.

List of fossil plants from the locality north-west of Thán.

FILICES.

* *Alethapteris* (*Asplenium*) *whitbyensis*, Göpp.

CYCADEACEÆ.

*Ptilophyllum cutchense*, var. *minimum*.

CONIFERÆ.

*Palissya jabalpurensis*, Fstm.
*Taxites tenerrimus*, Fstm.
* *Araucarites cutchensis*, Fstm. (seeds).
? *Pinus* comp. *nordenskiöldi*.

The two plants indicated by an asterisk in the above list are known in the Jabalpur and the Umia (Cutch) groups. Two others, the *Palissya* and the *Taxites*, were hitherto unknown in Umia's beds. Dr. Feistmantel writes (*loc. cit.*): "A comparison of these fossil plants shows that they are related to the flora of the Jabalpur group by the presence of *Palissya jabalpurensis* and *Taxites tenerrimus*; while *Araucarites cutchensis* is common to the flora of the Umia and Jabalpur groups."

Carbonaceous shale.

The black carbonaceous shale at the fossil locality north-west of Thán exhibits strings and laminæ of coaly matter, but not in sufficient quantity to burn as a fuel; neither is there promise of any useful fuel being found in the field. The existence of this carbonaceous shale has given rise to the reiterated report that 'coal' had been discovered in Káthiáwár, but this is fallacious, the facts being as here stated.

Arenaceous shale is also exposed at Amárpur, 2 miles north of Thán; at Samtherwa, 6 miles south of Máthak, and near Maika 8 miles to the southward of Wánkáner. At the last-named locality the rock is mottled purple and white; it has a fine silty texture, and is very brittle. No fossils were obtained, nor was the black argillaceous and carbonaceous shale observed at any of these places.

In the north-eastern part of the field, the plant-bearing arenaceous

shale was met with in two or three places on the road from Dhrangadra to Wáori on the Phulka stream. About half way, some mottled pale grey and purplish finely arenaceous shale is exposed at a *talaori*, and here and there along the *nala* leading into the Phulka stream opposite Isadara. The rock contains many fragmentary impressions of plants, some of which look like seed-wings (*Araucarites?*). At the junction with the larger stream, the shale is more compact and strongly bedded, and has been quarried to a small extent. The prevailing rock in the neighbourhood is the usual harsh and gritty whitish sandstone, the shale occurring as an inlier.

At Kúwa, on the Godra stream, a light-coloured very fine shaly sandstone bearing a few indications of plants is seen on the north side of the village.

An isolated patch of the Umia rocks occurs in the broad stretch of alluvium to the north of their main area. It extends for about 12 miles along the borders of the Ran; but is very much obscured by sandhills. The rocks are best seen in the eastern portion, about Handi Bet, where the scarped hills show a thickness of about 50 feet. The following beds were observed in descending order; their Cutch *facies* is at once recognizable :—

Exposures along the Ran.

(*a.*)—Hard black ferruginous grit, occasionally coarsely gritty, with white and colourless quartz and a few jaspery pebbles. It passes down into a thick bed of rusty-brown coarse grit of colourless and white quartz in a sandy matrix. Some of the quartz grains are sub-angular, while the rest are fairly worn. This rock also contains small lumps of a chalky earth.

(*b.*)—Below this come very thick cross-bedded sandstones, softer and less ferruginous, but still stained, mottled or streaky, yellowish brown, or red, finely speckled with white. Some thin ferruginous bands assume a scabrous appearance when weathered.

(*c.*)—The lowest rock seen is a white coarse and gritty sandstone, of roughly worn transparent white and bluish quartz grains,

loosely held together by a scant calcareous paste. The bed shows strong oblique lamination.

The general lie of these beds is horizontal or nearly so: near the Mandarki *talao* they are locally tilted 10°—15° to south-south-east.

The white sandstone is again seen at an outlying knoll in the alluvial plain between the two villages of Ghántila. It is more or less kaolinic, with occasional lumps of white clay enclosed; the quartz is partly sub-angular and dull cloudy white in colour, or dark blue in the coarser parts.

The hillock is masked with gravel mostly of flints and agates derived from the traps, the larger pebbles of which have accumulated on the northern side; as though left there by receding floods. (vide seq.)

*Wadhwán Sandstones.*—In the neighbourhood of Wadhwán Camp, and at other places along the edge of the traps, a set of sandstones is found overlying the Umia beds, but not decidedly separable from them.

The traps are very thin in the north-eastern division of the province, and their basal flows are seen to be strangely associated and tangled with the sedimentary beds below them. There are irregular accumulations of sandstone more or less impure, frequently unsorted in texture, and for the most part indifferently cemented, though sometimes indurated by local crush to hard rock resembling quartzite. Lumps of decomposed trap are occasionally seen imbedded in the sandstone.

The most prominent member of this group is a brick-red or dull reddish-brown sandstone, very prevalent in the vicinity of the Wadhwán civil station. This sandstone is fairly exposed in the river bank at and above the station. Here it displays local aggregations of small quartz pebbles, and also ferruginous nodules or galls; the bedding, which is very indistinct, does not indicate any displacement from its original horizontality.

Red sandstone with cherty bands.

In the upper part of this exposure, there are cherty and chalcedonic segregations, some of large size, which appear to consist of matted accumulations of organisms now much obscured by the silicious infiltration. Small spiral shells can be seen

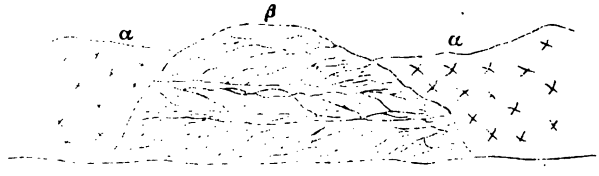
Marine organic remains.

in section on a newly-fractured face, but they cannot be developed sufficiently for determination, and many minute Bryozoa may be detected with a lens. A piece of silicified wood was also obtained from the same locality. The nature of the rock gives it a strong resemblance to the cherty members of the Bág beds.

The base of this peculiar sandstone is not exposed in the Bhogáwa river section, nor is its relation to the underlying rocks clearly displayed anywhere. Its association with the traps is, however, very well seen in a ravine a mile or so to the west of the station, where the latter abuts against and partly overlaps the sandstone.

The same rock is exposed for a limited extent in the ravines on the north side of the town of Sitha, 10 miles north of Wadhwán station: but its association with the trap alongside is not so clearly seen as in the former locality. The thickness of the sandstone here, however, must be considerable, if the native testimony be true that a well was sunk to a depth of 50 cubits piercing no other kind of rock.

In the Morvi State to the westward, the Wadhwán sandstone is again seen, but very sparingly. The stream at Jhinkiáli, 12 miles north of Morvi, has exposed both the red and other sandstones of this possibly cretaceous group. In the right bank of the stream about 300 yards above the village, is a large boss or dome-shaped mass of brick-red softish sandstone, readily weathering and reticulated with calcite. This mass is nearly surrounded and overlapped by decomposing traps, as shown in the following sketch section:—




Sketch Section
α. Trap β Sandstone

The stream bank at the village shows a section of 30 or 40 feet of various soft sandstones—yellow, red, and light-coloured, lying horizontally. Similar beds are again exposed, to the east of the village, in the

banks of a watercourse, where they are overlaid by the traps of the surface. The basal traps are, as usual, much decomposed, friable, and very various, and are associated and mingled in a confused manner with the sedimentary beds; some of the latter have even a trappean aspect; and it seems probable they were being deposited when the trappean epoch set in.

Inliers east of Morvi.

East of Morvi town the traps are very thin, and several small inliers are exposed of varying sandstones that I am disposed to regard as members of the present group. The red unsorted softish sandstone is prevalent, and associated with other light-coloured slightly calcareous sandstones, with some argillaceous bands. The inlier south of Ghotu is a tough compact, rather calcareous gritty sandstone. It is cross-bedded, and appears tilted four or five degrees to east-30°-south. A similar rock crops out below the trap scarp near Páneli, and may be traced nearly as far as Gidach. Umia sandstones occupy the low ground and plains. In the scarps of the two outlying trap-capped hills south of Páneli, red sandstones varying to orange or yellow, unsorted in texture and gritty, and slightly calcareous in part, form one-third of the hill-sides. At the southernmost of the two hills, the unsorted gritty sandstones are more massively bedded, and are seen to rest upon the somewhat uneven surface of the Umia sandstones of the plain.

Inliers south-west of Wadhwán.

Isolated hillocks of similar gritty slightly calcareous sandstones occur in the Wadhwán district, forming inliers, which protrude, as it were, from under the thin traps of the plain. The matrix of the sandstone is sometimes observed to be porcellaneous. The sandstones in the area between the two Bhogáwa rivers, are often locally disturbed, being tilted as much as 60°, or more, from the horizontal: and the rock occasionally presents the appearance of induration and crush where slickensides have been developed. The displacement, in some instances, appears to be merely superficial; as though the surface beds, while yet unconsolidated, had been ploughed up by the flowing lava—erupted through

long fissures, which are indicated by the very remarkable trap dykes to be described further on;—or otherwise disturbed by earthquakes and floods, that must have accompanied the ushering-in of the great trappean, or fissure-eruption period.

A few Bryozoa, and indefinite organisms, can be detected in some of these beds, but they are not conspicuous. Among the disturbed rocks is occasionally observed a drab-coloured, tough, sometimes gritty and chalcedonic, organic limestone of marine origin. It is almost invariably displaced, and its relations with the associated rocks are very obscure. The fossils are chiefly Bryozoa in a matted mass of indefinite shells, (like *Natica*, and broken bivalves,) and a few small corals. One small Echinoderm and some spines were obtained, but too imperfect for identification, and a portion of a flattened keeled Ammonite, that in some respects can be compared to *Am. guadaloupæ*, Roem., a well-known cretaceous fossil.

Marine limestone ? cretaceous.

The limestone, which varies from a few inches to about four feet in thickness, is seen in the stream section two miles north-west of Bhádúka, also in the Bhogáwa river near the village; and again about a mile and a quarter south-east of the village, there are two small outcrops. In all these places it is displaced and in tumbled association with volcanic and other rocks. The limestone was also noticed two miles north-east of the Chotila dák bungalow, as a small patch between two little outlying trap hills. It is here only a very thin shaly band underlying the trap, and resting upon dark purplish-red coarse open sandstone, which is apparently an outlier of the Wadhwán beds, since it rests upon recognisable sandstones of the Umia group.

The rocks on the eastern flank of the trap hills four miles east-north-east of Chotila are very similar to those just described: there is the Wadhwán sandstone, enclosing masses of a strange rock (? volcanic), and a band of gritty limestone, a few inches only in thickness, associated with various nondescript shales and sands. The limestone contains many fragments of Bryozoa, and of shells, besides a few very small corals. It was from this locality that the small imper-

fect echinoid and spines were obtained. This bed is tilted at about 80°, to south-30°-west. The sandstones with which the band of gritty limestone is associated are also turned up at the same angle just at this spot. There is no clear section, and the rocks are confused.

At Bhádúka the limestone is cherty, with small segregations running in the direction of the bedding; it is, as usual, tilted and displaced. There is here a still greater confusion among the rocks; traps are very various, including volcanic ash and agglomerate. A coarse unlaminated sandstone—evidently a rapid accumulation, as from floods—contains rounded masses of decomposed amygdaloid, and portions of other rock.

In the small *nala* on the south side of the high road east-south-east of Bhádúka, the organic limestone is seen in thick masses tilted on end. The rock is somewhat silicious and very tough. It was from this locality that the flattened keeled ammonite was obtained, together with a small *Ostrea* and a crenulated *Natica* (*?*), besides some small corals. In the *talaori* at the head of the *nala*, there is a small outcrop of the limestone apparently dipping 5° south of east at 50°—60°, but no other rock is exposed there.

Near Sidsar, a village three miles north of Sáyla (Sáhilá) in the Wadhwán district, a few imperfect fossils (mostly fragments of an ostreoid shell) were obtained from a crumbling calcareous sandstone associated with impure limestone and various other thin bands. The whole extent of the exposure does not exceed a few yards, and they are covered up by traps close by.

Near the village of Timba, in the stream that passes by Khárwa, south of Wadhwán city, there is an instance of abnormal intercalation of sandy beds among the basal trap flows. Trap is seen both above and below these at this point of the section; but in other parts of the section, sedimentary beds are tilted at high angles, and the conditions appear abnormal, as though the margin of the latter had been turned up and imbedded by the trap flow.

Further down the stream there is, in the vicinity of Khárwa, quite a jumble of various and heterogeneous traps with sedimentary accumu-

lations, of very varied and nondescript character, much weathered and disintegrated, and covered with saline efflorescence. One of the traps has an agglomeratic appearance, the imbedded lumps and masses being dark and scoriaceous. These traps also disintegrate rapidly, and are impregnated with salt. In almost all places where the perturbed accumulations at the base of the traps are exposed, both the sandstones and the associated traps are intensely saline.

At Sejakpur and in the tributary stream to the north that, for some way, forms the boundary between the Sáyla and Sejakpur *taluks*, a similar jumble of rocks is seen at the base of the traps, and is further complicated by masses that appear to be intrusive. It is often impossible to determine from surface examination only, whether some of these decomposed and queer-looking traps are really intrusive, or merely displaced masses of volcanic rock. They are too irregular and ill-defined in shape and direction, to be regarded as dykes; moreover, most of the dyke trap is compact, whilst these masses are frequently amygdaloidal, yet differ much from the regular bedded traps.

These strange and complex rocks are, perhaps, best seen in the neighbourhood of Bháduka, and along the channel of the Bhogáwa river, as far as Godávari. At Shekhpur, a village a little lower down, a large open irrigation well shows the following section. At the top is basalt, then below comes an earthy chocolate-brown argillaceous rock with enclosed lumps of decomposed amygdaloidal trap. These lumps are sparingly scattered in the upper part, but become more abundant below, and towards the base constitute (together with other miscellaneous trap fragments) the bulk of the rock mass. The subjacent strata were not seen, but the agglomerate here is in all probability the bottom bed of the trappean series.

At the most southern limit of the sandstone area, in the south part of the Chotila district, a small but interesting section is exposed in the right bank of the stream passing Mewása, about a mile below the village. At this spot, the traps are seen to rest unevenly upon a bed of soft coarse sandstone, in which are imbedded lumps and fragments of trap; thus

showing that this bed was accumulated at, or immediately subsequent to, the beginning of the trappean outburst. The sandstone is gritty, and finely conglomeratic in part, though distinctly laminated; and the enclosed lumps of trap are scattered irregularly and sparingly, here and there, through it. The base of the bed is not exposed.

*Trappean grits.*—The laminated gritty and trap-like deposits, so strongly developed at the base of the traps in Cutch,[1] are but poorly represented in northern Káthiáwár, by an isolated thin patch or remnant, of about three square miles in extent, in the plain four miles to the north of Thán. The rock is identically the same as that in Cutch, having a yellowish or olive-green colour, and a decomposed trappean appearance. It is more or less sandy or gritty, with quartz grains, and has a laminated, or rather shaly structure. It was, doubtless, a volcanic product deposited in water along with sand.

Gritty volcanic rock near Abhepur.

On the south side of a low ridge of sandstone, running from Abhepur towards Thán, there is an isolated mound, or boss, of broken rock projecting above the cultivated soil. The weathered surface is dark, with a rough gnarled and scoriaceous appearance: internally, the rock has a light grey colour varying to shades of brown, and an agglomeratic (or at least heterogeneous) structure, and is gritty with quartz granules. It is undoubtedly of igneous origin, but the difficulty is to account for its isolated position,—supported, as it is, on ordinary light-coloured Umia sandstone, which is visible on three sides of the mound. It appears to occupy a hollow on the surface of the sandstones; the mound itself is not more than 20 yards in extent; there is no bedded trap in the neighbourhood. Another small exposure of similar rock occurs about a mile and a quarter to the south, among sandstones which are disturbed and slightly faulted with dykes, but its position here is not the less enigmatical.

The miscellaneous accumulations of earthy felstones, volcanic ash

[1] See Memoirs, Geol. Sur., India, Vol. IX, p. 56.

and agglomerates, occurring in many places at the base of the bedded traps, are probably about the same date as the trappean grits. They not unfrequently occupy hollows, or depressions, in the sandstone floor on which the traps are superimposed. In the vicinity of the village of Mewása, ten miles south of Chotila, various rocks—ashes, felsites, &c.—are seen filling irregular hollows of the Umia sandstones near the scarped margin of the trap area.

Some of the earthy felsitic rock, which is mostly in a decomposed state, is porphyritic with a white and pale-green soapy mineral; other parts have a brecciated, or agglomeratic appearance.

*Traps.*—In the foregoing section, I have treated mainly of the miscellaneous volcanic accumulations belonging to the inception of the great Deccan trap period; in the present section, we have to deal with the bedded trap-flows. The trap formation in Káthiáwár—unquestionably an extension of that in Cutch on the one hand, and of those in Guzerat and Malwa on the other—stretches from the east coast at a point below Gogha, to the western shore, where it sinks below the Gulf of Cutch. It prevails to within a few miles of the southern coast, where it is overlapped by tertiary and post-tertiary deposits. North of Bhávnagar it is covered by alluvium. In the northern division of the province, the bedded traps have been so much denuded as to expose the underlying formations already described.

Bedded traps.

The accumulative thickness of volcanic rock in the Girnár mountain cannot be less than 3,500 feet, but one-half that amount will suffice for the thickness of the bedded traps throughout the greater part of the field.

Thickness.

The trap rocks of Káthiáwár resemble, in nearly every respect, those of the Deccan and Malwa in Peninsular India. Basalts and dolerites mostly prevail, but felstones, trachytes, diorites, and obsidian also occur, and beds of scoriacious breccia are occasionally met with. The several flows vary considerably in character; those nethermost are often decomposed, and in places agglo

Varied character.

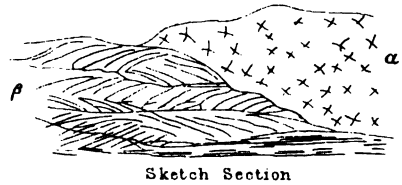
meratic, while the later outbursts are more trachytic, felsitic, and dioritic, occasionally with lenticular masses and thin bands of uncrystallized rock, resembling obsidian, or pitchstone.[1] Some of the trap-flows are thoroughly crystalline, often showing a porphyritic appearance on the weathered surface; others are more homogeneous, compact, and aphanitic; while others again are more or less decomposed, many of these are highly amygdaloidal. In the western part of the field, especially north of Rájkot, zeolites are abundant in the decomposed traps, occurring often in large crystalline masses; and geodes of agate and chalcedony, lined with quartz crystals, are also numerous.

Zeolites abundant.

The traps are, as a rule, thinly bedded: in a scarp of 320 feet, nine miles south of Chotila, one may count, from a distance of many miles, at least eight superimposed flows, thus giving an average of 40 feet for each; but several of them are not half this thickness, and probably there are many more flows than can be superficially discerned. It may be mentioned that the great dyke passing Mewása has cut through all the beds in the scarp just referred to.

The nature of the floor, wherever the traps rest on Umia sandstones, is often irregular and uneven, showing distinct unconformity. The annexed sketch section, showing such an unconformity, was taken in a quarry at the sandstone inlier between 6 and 7 miles west-south-west of Chotila.

Varied floor.




Sketch Section
α Trap β. Sandstone.

I have already stated that the basal part of the trappean series is frequently very miscellaneous; but this is not always the case; notably in the hilly country west and northwest of Chotila, where a homogeneous trap-flow is seen resting, with apparent conformity of bedding, upon Umia sandstone,

[1] It is nearer obsidian than pitchstone; its hardness is from 6 to 7; it is slightly decomposed by acid. Before the blow-pipe, however, a splinter fuses to a frothy light-grey glass.

without any intervention of mingled miscellaneous deposits. The sandstone is here indurated by infiltration of silica.

Volcanic ash in Chotila hill.

In the lower part of the Chotila Hill, there is a thick bed of volcanic ash, made up of fragments, from the size of gravel, or grit, to occasional large lumps of a dense trap: the layers of this accumulation slope at angles of 30 to 35 degrees. The matrix is mostly decomposed, and the rock disintegrating. The upper part of the hill is of fine-grained compact basalt. To the south of the hill the base of the trap is seen to be a very heterogeneous accumulation resting on sandstone.

The trap rocks attain their greatest development in the southern division of the province, where there are several groups of hills of considerable height. Many of these are mainly composed of various kinds of felsite and diorite, with some trachyte and occasionally pitchstone. These rocks appear to be among the later eruptions of the trappean period.

The Gírnár, or Junágarh, group is the most important and interesting, from its singular and imposing form and proportions.[1] The topographical features of this group have often been described,—the great central mass called the Gírnár, over 3,500 feet in height; and the outer annular ridges, steeply scarped on the inner side, but sloping away at varying inclinations outwardly.

The Gírnár a focus of eruption.

The Gírnár mountain is a majestic pile of diorite rock, with terrific scarps and precipices, propped by diverging buttresses, which, inosculating with the surrounding ridges, give rise to four distinct areas of drainage, each discharging through one of the four gorges in the outer ranges. This central pile, which is far loftier than the surrounding ridges (save that to the south, whose highest point nearly rivals it), assumes somewhat the form of a huge cupola, laterally compressed, and is crowned by several sharply defined peaks of an extremely precipitous and picturesque character;[2] the loftiest attains a height of 3,666 feet above sea-level.[3]

[1] See frontispiece.

[2] The crest of the mountain and some of the peaks are adorned with many Buddhistic and Jain temples of richly carved stone.

[3] This paragraph is mainly derived from Mr. Theobald's MS. description, written in 1858.

The Gírnár appears to have been produced by a volcanic eruption of considerable magnitude towards the close of the Deccan-trap period; and the mountain, in its entirety, must have attained vast proportions in comparison with its present denuded appearance. The great central mass now represents so much of the core, or plug, of the vent, the outer portion having been more readily removed by denudation, owing to the decomposition of the component minerals.

Diorite of central peak.

The diorite of this central peak has not been found in any other place in Káthiáwár; nor, as far as I am aware, in any part of Peninsular India. Its normal form is a black and white crystalline-granular rock of hornblende and felspar; it has much the appearance of syenite, but the felspar is almost entirely plagioclastic. This rock passes into micadiorite where it contains black uni-axial mica more or less abundantly, not unfrequently in tabular segregations, enclosing felspar. Some portions of this rock are richer in felspar, with chatoiyant blue lustre, and more coarsely crystalline. Microscopic sections of the rock display magnetic iron, apatite, and garnets occasionally. Other portions are minutely crystalline, or even aphanitic.

Diorite of two kinds.

In the basal and outer portion of the central pile two marked varieties of the diorite are prevalent. The most conspicuous is a light grey semi-aphanitic diorite, with porphyritic crystals of felspar, and some bi-axial mica sparingly; in this variety hornblende is extremely deficient. The other variety is of a dark grey or black colour, from its richness in hornblende, and is often seen intermingled and banded with the paler rock, with which it affords a very striking contrast.

"From the strongly marked line of demarcation which often separates these two varieties in the same rock, it might be presumed that one was of later date than the other, and had penetrated it subsequently to its consolidation; especially as many of what appear like included fragments of the older, have a very angular and irregular outline. But this appearance is in reality deceptive, the pale variety being found enclosing lumps, sheets, and strings of the dark kind, and *vice versâ*, thereby con-

clusively proving the appearance in question to be merely the result of the peculiar arrangements of the component minerals."[1]

Decomposed quartz-diorite in the valley.

The rock occupying the hollow, or valley, between the central peak of Gírnár and the surrounding ranges, is a third variety of the diorite, consisting of a granular mixture of felspar and hornblende, the latter in fair proportion; with free quartz and a sparing addition of rusty black mica. This variety is remarkably prone to decomposition, and at first sight much resembles decomposed gneiss; it is only in the small lenticular masses, which have escaped decomposition, that the true nature of the rock can be detected, its usual condition being that of a friable mass, which crumbles on handling.

Greenstones of the outer ranges.

The surrounding, or outward annular, ranges are composed mostly of various greenstones, to which it is not easy (without a close study with microscopic sections) to assign specific names. Some are felsitic, very tough and compact; others are basaltic, with much olivine: free quartz is not uncommon in a few. These rocks seldom present either the bedded structure, or the terraced appearance, of ordinary trap-flows, so commonly seen in other parts of the district. Yet some of the greenstones appear to slope almost as steeply as the hill-side; while a general outward, or quâquâversal, inclination is perceptible throughout the annular ranges.

Quartz-felsite along the axis.

The axis of the western range, which is very steep, and crested with a precipitous jagged ridge, consists of an extremely tough and durable quartz-felsite, containing plagioclase, quartz, and magnetite in a micro-crystalline base.[2] It has the form of a huge dyke, or vertical intrusion. On the west flank of this western range is a bluff of rock, which assumes the aspect of gneiss, especially in its mode of weathering; but a microscopic examination of a thin section shows it to be a finely-granular quartz-felsite.

[1] Mr. Theobald's manuscript written in 1858.

[2] The "Asoka stone," as it is called, on the polished surface of which is engraved the celebrated edict of Asoka (B.C. 250), is a rounded boulder-like mass of this rock.

Mr. Theobald mentions in his manuscript report[1] the occurrence, on one of the spurs of the hills south-east of Junágarh, of a "small patch (whose exact extent I have not yet traced) of metamorphosed rock[2]—a coarse quartzite, with bands of conglomerate irregularly disposed through it, containing numerous rolled quartz pebbles." I myself picked up in the plain beyond the western range, a specimen answering this description, an altered conglomeratic quartz grit; but the rock was not found *in situ*, and I take it to be an indurated portion of some pre-trappean bed floated up with the lavas of the period under consideration.

Osham hill.

The hill of Osham, which rises abruptly out of the plain 14 miles west-north-west of Junágarh, is an isolated block, mainly composed of homogeneous trachytic felsite, boldly scarped and presenting in many places beetling cliffs of 200 feet and upwards in height. The eastern base of the hill consists of a soft, decaying amygdaloid, with kernels of a yellow soapy mineral, and quartz geodes. The thickness of this bed is not seen. Above it, but generally concealed by a talus of fallen rock, occurs a bed of pitchstone a few feet in thickness, thinly laminated, but granular and friable in part. These two rocks constitute barely one-fourth of the hill-side, the summit being composed of a thick mass of the trachy-felsite, the fallen blocks from whose steeply-scarped sides conceal to a great extent the softer beds on which it rests. This trachy-felsite is also much laminated, and presents the appearance of woody fibre, which results from the curvature and involution of the planes of lamination, which themselves seem to arise from the movement of the mass when in a viscous, or pasty state; so that the laminæ are often seen horizontal and then bent down, and rolled over, as from the gradual progression of the mass. The surface of the laminæ is either smooth or rumpled.[2]

Pitchstone and trachy-felsite.

The beds in this part of the hill have a slight slope westwards, but in

[1] Season 1857-58.
[2] Mr. Theobald (*loc. cit.*)

the western scarp no succession can be traced. The greater part of this side of the hill consists of a vitreous, aphanitic compact trap; it is banded and contorted, and parts vary from trachy-felsite to obsidian, the latter occurring in alternating layers a few inches in thickness, and following the sharp contortions of the rock mass. Parts of this rock are agglomeratic, with rounded lumps and irregular masses of obsidian, and of a green trap, whose crust, or outer part, passes into the rock mass. Slikensides was observed on a few of the enclosed lumps, the composition of which is often identical with the enclosing matrix.

Barda hills.

The Barda hills consist of rocks very similar to those in the western ridge of the Junágarh mass. A porphyritic quartz-bearing felsite prevails in the northern part of the Barda group; the rock has the appearance of having undergone change, or partial decomposition; it contains free quartz in abundance, some at least of which is a secondary product. It is very similar to the gneissic-looking rock on the west flank of the western ridge of the Junágarh hills. A closely allied rock forms the hills in the southernmost part of the Bardas; but, besides the contained crystals of quartz, there is another vitreous constituent, amber-coloured, and below quartz in hardness. A third variety, associated with the latter, is a pale-grey trachytic ash, which contains a decomposed wax-green soapy mineral. These rocks weather into huge spheroidal, or boulder-like masses, piled one above another. In the neighbourhood of Morpur, and of the deserted place called Gúmli,[1] a very tough granular quartz-felsite prevails; this rock much resembles that forming the axial portion of the western range in the Junágarh hills. The outlying ridge of hill at Dhebar on the north side of the Bardas, consists of a dull fawn-coloured crypto-crystalline, or minutely granular felsite.

Quartz-felsite and trachytic ash.

Hills near Dhánk.

The group of hills north and north-west of Dhánk consists of various kinds of felsites, that would require a closer study than I have been able to give them, to define their

[1] At Gúmli or 'Ghúmli,' a former capital of the Jáitwas (or 'Jethwás'), there are extensive ruins, including some exquisitely carved stone temples.

specific varieties; some are very compact, tough, and silicious; others are trachytic.

Compact earthy felsitic rocks are also met with in several other parts of the trappean area. In the eastern division of the province a laminated, or striped, felsite prevails, as, for example, in the hills at Sihor, 12 miles west of Bhávnagar, and again at Rájula, near Jáferábád. It is often porphyritic and in part agglomeratic. At the former locality the rock is extensively quarried for building purposes, while at the latter place it is worked for querns, or hand-mills.

The Sihor, or Sonpuri, range.

The hills west of Bhávnagar, called the Sihor range, though broken and irregular in outline, have a general bearing east and west. The trap beds, of which these hills are composed, are tilted slightly, showing a tolerably uniform easy slope towards the south, while their northern outcrops form a long scarp running east and west. At the foot of this scarp commences an extensive alluvial plain, which stretches away northward, beyond the limit of the province.

Obsidian and pitchstone.

In the broken hilly ground opposite the town of Sihor, a band of obsidian was observed among contorted and irregular trappean rocks. Mr. Theobald observed a bed of 'pitchstone' in the hills near Rájula. He writes (*loc. cit.*): "At the base occurs a bed of very amygdaloidal trap having much the aspect of some of the Deccan amygdaloids. Above this rests a thick bed of pitchstone not less than 20 feet in thickness, very compact in parts, and these breaking with a highly conchoidal fracture. This bed can be traced for 15 miles to the eastward (E.N.E.), in which direction it gradually dips, eventually disappearing beneath the surface." A bed of pitchstone is also exposed in the Bhádar stream bank at Nágnesh below Ránpur: it is here very impure, enclosing fragments and lapilli of volcanic products; above it is a bed of sphæroidal felsite, whose nodules have a nucleus of chalcedony. Below the bed of pitchstone, which becomes trachytic in the lower part, is a compact felsite of a dull red colour; this latter rock has been used in the wall round the town of Nágnesh.

Chamárdi and Chogát hills.

A group of seven or eight small isolated rocky hills, about 16 miles west-north-west of Bhávnagar, rises abruptly from the alluvium, presenting the appearance of mountain tops that have escaped submergence. The largest and highest of the group is nearly a mile long and reaches an elevation of 340 feet above the plain, which is scarcely 20 feet above sea-level. These hills, which may be called the 'Chamárdi group,' are composed mainly of similar rock to that found in the Bardas and in a part of the Gírnár; and they would seem to indicate another centre of eruption. Those nearest the village of Chamárdi consist of quartz-felsite rich in felspar, and approaching syenite. Though a solid-looking rock in a hand specimen, it weathers unevenly, and is not valued as a building stone. That in the hill south of the Chamárdi stream is a greenish grey and dark crystalline diorite; a similar rock, but more distinctly crystalline, giving a black and white appearance, forms the larger of the Chogát hills, while the smaller consists of a compact and very hard felsite.

*Inter-trappean beds.*—Sedimentary deposits interstratified with the trap flows are seldom met with in Káthiáwár, and the few places where they have been observed are situated at no great distance within the northern margin of the trap area; and, as usual in other parts of India, the inter-trappean horizon is not far from the base of the formation.

Porcellaneous shale west of Chotila.

A cherty porcellaneous shale crops out from the sides of the hills near the road, two or three miles west from Chotila, and is seen again to the south, in the broken ground round about the villages of Kherdi and Kálásar. The bed is more conspicuous near Bámanbor and Nawágám, about ten miles from Chotila, on the road to Rájkot. At this latter locality some organic remains, mostly imperfect skeletons of very small fish, were detected, but they are not abundant. The shale here displays evidence of severe lateral compression, the laminæ being crumpled into small folds that give the appearance of ripple mark to the surface of each stratum.

Limestone at Ninámá, &c.

The fort hill of Ninámá, twelve miles south-east of Chotila, is capped with a bed of inter-trappean limestone. The same bed is seen cropping out near the top of an adjacent hill; and it was again observed capping the ridge scarp between Lákháwand and Shekdod. The bed is there sloping, at a low angle, southwards, in which direction it becomes covered up by later flows of trap. The maximum thickness is about ten feet, and the rock consists of argillaceous limestone, very tough, close, and in part cherty. At Ninámá it is somewhat flaggy, or roughly banded, and has been largely used in building the walls of the fort.

*Trap dykes.*—In certain parts of the province,—more especially in the central and south-eastern portion of the trappean area, and in the jurassic field beyond the present boundary of the traps,—dykes are very numerous and large, often forming prominent features in the landscape. Many of the dykes are traceable for long distances; the large Sardhár dyke extends for about 45 miles from end to end, and in some parts has the appearance of a great rampart in ruins. At Sardhár, it is nearly 100 feet across. The general bearing is east and west, this being the prevalent direction of the dykes in that part of the country; though they may be irregular for some portion of their course, and even interrupted or not visibly persistent throughout; or they may bifurcate. Several cross-dykes bear north and south, or north-by-west and south-by-east, and are generally of a later date than the east and west set. Indeed, the dykes are so prevalent and strongly displayed, that they can hardly be regarded otherwise than as indications of the fissured and crevassed state of the stratified crust of the earth during the period of the trappean eruptions.

The Sardhár dyke.

Surprise has often been expressed at the absence of volcanic vents within the trappean area, but the fact, that the Deccan trap period was a period of fissure eruption, is not sufficiently borne in mind. When we contemplate the

Sources of discharge.

enormous volume of discharge that these numerous and extensive fissures afforded, there is no need to look for volcanic vents, or *foci*, although, in the Gírnár mountain and a few other hills, there is some evidence of the latter kind of discharge at the close of the trappean outflow.

Nature of dyke-trap.

The character of the dyke-trap generally differs from that of the adjacent flows, or beds; this may probably arise from the difference of condition under which the matter solidified. The rock, in very many of the dykes, has a prismatic, or columnar structure, transverse to the direction of the dyke. In very few instances was the dyke-trap observed to be amygdaloidal, or vesicular; and where such is the case, it may be presumed to occur near the surface, or overflow: at this latter point a dyke would naturally become ill-defined and blended with the lateral flow. This, indeed, appears to be the case in the dyke at Harmaria, north of Mewása, where the dyke-rock, in places, is indistinguishable from the adjoining bed, or flow, and is only traceable as a dyke here and there by irregular lines of contact.

Variety in aspect.

The long dyke west of Charkhari (north of Mewása) displays a different structure at different levels within its walls; where seen in the bed of a *nala* it has a fissile splintery structure, is very close-grained, or micro-crystalline; while, at a higher level of the same dyke in the hill ridge above, the rock has lost the characters just described, and has assumed a spheroidal, or boulder-like, structure on the weathered surface, and internally is more distinctly crystalline.

The Khokhri dyke (south of Gondal) is 120 feet wide east of the town, and may be as much as 200 feet in some parts, but its decomposed sides and walls are not clearly defined.

The great dyke running eastward from Karmál Kotra, and twice crossed by the Bhádar river, east of Gondal, is more like an irregular intrusion than a fissure dyke. It is very irregular without definite walls, and in one place it has a bedded appearance.

Differently bearing dykes have different kinds of trap.

Among the dykes north of Wasáwad, those in one direction are of one kind of trap, while those crossing are of a different kind. The north-east, and east-north-east, set have a crystalline texture, with grey felspar and black hornblende; the rock is massive, or transversely columnar: while the north-west and south-east dykes have a much finer texture, are micro or crypto-crystalline, and the rock—which is dark grey internally, but weathers to a pale olive green on the surface—is fissured into angular shingle, or gravel, along the surface of the dyke. This latter set, it would appear, is the older; for, in several instances, the dykes of this series were cut through by those of the other. It was also observed that the dykes with the splintered fine-grained trap with olive green surface (*i.e.*, the older dykes) are more regular, on the whole, than the others: they are long and straight in their course, or nearly so, and uniform in thickness throughout: they seldom make much show above the surface of the country, at most forming low knolls, or elongated mounds, hardly perceptible from a distance; whereas the more crystalline lumpy boulder-like trap-dykes are most irregular in their bearing, vary much in thickness, and often die out rapidly, or terminate abruptly, starting again, perhaps, a little out of the normal bearing. They almost invariably form ridges that may be traced by the eye across country for many miles. Some of these ridges attain a height of 150 feet above the level of the surrounding country; as, for example, the one north-east of Kotra Pita that passes the deserted village called Bhabhisana. These ridges are buttressed, or fringed, on either side by remnants of bedded traps removed elsewhere by denudation.

Exceptions.

There are exceptions to the rule given above, that dykes trending in one direction bear the same kind of trap; for instance, of the eight dykes more or less parallel, north of Dárwa, and all within two miles of the village of Umrála, five are of the fine-grained trap that weathers on the surface into angular gravel, while three are of a coarser variety of trap weathering into large boulder-like masses.

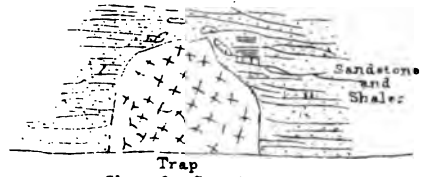
Many of the larger dykes are strongly magnetic, owing to the amount of magnetic iron entering into the composition of the rock.

Dykes in Umia sandstones.

The ground, in the south-western part of the jurassic field, to the north of the present limit of the trappean area, is closely intersected by trap dykes, more especially in the neighbourhood of Thán, where they form quite a tangled network on the surface of the country.

Some of these filled-in rents are traceable for a distance of 30 miles; others may be equally extensive, though not continuously exposed, their several parts not being visibly connected.

While certain of the dykes may be traced to within the trappean area, where they have penetrated vertically through 300 or 400 feet of bedded basalts, others do not persistently reach the surface even of the sandstones. The annexed sketch of a section in the bank of the stream between Sarsána and Morthala, north-west of Thán, will illustrate the latter instance. The dyke here shown was traceable in the bed of the stream, and again further on, after being lost on the surface for a short distance.



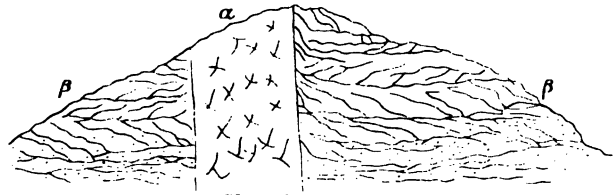
Sketch Section.

The dykes in this neighbourhood are mostly of large size, few being under 8 feet in width; one north of Thán measured 32 feet, but there are others still broader. Occasionally a partition occurs along the middle of the course, formed by a mass of sandstone detached from the walls. The walls, as a rule, are vertical, or very nearly so, with clean well-marked faces, and often coated with silicious slickensides, as are also the sides of the enclosed masses.[1]

Slickensides on the sandstone walls.

[1] Some excellent examples were obtained of enclosed pieces of sandstone with slickensides on either side, and so intensely indurated as to resemble gneiss. They are now exhibited among the physical specimens of the Survey Museum.

Other evidences of great compression, and vertical motion, are displayed in the up-turned edges of the adjacent beds, not unfrequently seen on one or other side of the dyke, as shown in the accompanying sketch section.




Sketch Section
α. *Dyke.* β. *Sandstone.*

The effect of a dyke, on the sedimentary beds traversed, is generally to indurate, and at times to blacken or to bleach the rock for a short way on either side: and the hardened portion, being the better able to resist denudation, often remains as a narrow craggy ridge along the course of the dyke. This feature, together with that of the upturned edge of the wall-rock, enables one to trace the course of a dyke, even when no trap is visible on the surface.

The dyke-trap in this part of the field is almost invariably either a fine-grained compact blue-black basalt, or otherwise is in the decomposed state of '*wacke*'; it is never largely crystalline nor porphyritic, as many of the bedded flows are. The basalt of the dykes, as previously stated, is usually columnar, the prisms lying horizontally, and transverse to the direction of the course, *i.e.*, at right angles to the walls, and in the line of greatest resistance; whereas the prisms of bedded columnar trap are generally at right angles to the bedding.

Dykes transversely columnar.

In the broader dykes the trap may be columnar on either side, and decomposed in the middle, or *vice versâ*. This transversely columnar structure being peculiar, enables one to detect a dyke and note its direction when there may be no other indications.

Some of these basaltic dykes, having resisted the denuding agencies more effectually than the neighbouring rocks, stand up like the ruins of a great boundary wall across the country: a fine example may be seen just within the hilly ground 4½ miles south-west of Chotila.

No system as to the bearing of the dykes in the jurassic area could be traced, for they trend in all directions.[1]

Intrusions north of Chotila.

There is, about a mile and a half north of Chotila, a small group of irregular intrusions of fine-grained compact blue-black basalt. That these are actually intrusions, and not remnants of a trap flow, is shown by the altered indurated state of the adjoining sandstone; and further evidence is afforded in the frequent occurrence of slickensides here, caused by the pressure of the out-flow.

Dykes numerous in south-eastern area.

Numerous large dykes are shown on the map in the south-eastern part of the trap area, in the vicinity of Dedán, and thence north-eastward as far as Talájá. The hill ridges, formed by these dykes, have been so clearly delineated by the Topographical Survey, on their large-scale map, that I have not hesitated to colour the dykes on them, as time could not be spared to traverse the whole area. It will be seen that the general bearing of the dykes in this part of the field is west-40°-south to south-west. A few cross nearly at right angles. In the north-eastern part the bearings are less regular.[2]

Distribution.

*Lateritic rocks.*—This group, in the southern and south-eastern divisions of the province, is only exposed in a few places along the margin of the trap area; notably,

[1] It was observed that the agriculturists persistently sink their irrigation wells along the dykes, tracing out their course with great assiduity; they are almost invariably rewarded by the wells yielding water at a depth within 15 to 20 feet of the surface. In some instances it would appear that the joints and cracks in the dyke-rock communicate with some deep-seated water-bed; in other cases the dykes seem to wall up, and keep in on one side, the water of the adjoining strata.

[2] The map published with this memoir is on so small a scale, that only a limited number of the dykes can be shown; very many more have been recorded on the large field-map in the Geological Survey Office.

to the south of Bhávnagar, where it occupies a continuous though narrow belt, about 20 miles in extent. It is for the most part overlapped by tertiary and alluvial deposits. In the western division of the province, however, where the trappean floor is nearly horizontal, some large spreads of the lateritic rocks occur along the border between the traps and tertiaries; also as outlying patches resting on the former, and as inliers well within the area of the latter formation. These inliers are in the form of hillocks, crags, and bluffs rising over the plain, having resisted the denudation prior to the deposition of the tertiary beds that surround them.

The lateritic rocks in Káthiáwár closely resemble in many respects those in the neighbouring provinces of Cutch and Guzerat; and are to all appearances identical with the 'high-level laterite' and its associates of Peninsular India. They are generally unstratified, richly coloured, mottled, or white; the more lateritic bands are frequently strongly ferruginous, developing into red hæmatite.[1]

Varieties of the rock.

Among the laterites may be noted a softish earthy rock of lavender-grey colour, blotched with a white decomposed mineral; another variety is a concretionary and partly conglomeratic grit, of argillaceous pellets and nodules in a dark ferruginous matrix: a third is a decomposed brecciated ash, or tuff, consisting of white and faintly mottled soft soapy clay (in places indurated and deeper in colour), enclosing lumps and lapilli of similar rock, but more richly coloured and more earthy than steatitic; these enclosures sometimes form the bulk of the mass. This last variety was observed in a large excavation for a well at the village of Bakharla, north-north-east of Porbandar, and at other places in that neighbourhood. Its position is below the strongly ferruginous and lateritic beds of the rising ground to the west of the village. The same kind of rock was also seen near the base of the lateritic section west of Habardi, south of Asota, near the Gulf of Cutch. The

[1] This ore was largely worked and smelted in former days, but the industry was given up about forty years since owing, in great measure, to thec heapness of the imported metal.

indurated ash occurs in the lateritic area about three miles south-west of Asota. The second variety mentioned above may be seen to the east of Visawara above Porbandar.

Much of the ferruginous red or mottled earthy rock has the appearance of decomposed and lateritized volcanic ash; that at Tukra near Miáni,—in the form of craggy hillocks, or rising ground, sometimes supporting a remnant or thin capping of tertiary beds,—contains semi-crystalline lumps of a white partially decomposed mineral, which is probably of secondary origin; it is too much altered for recognition. The same, or very similar, rock appears about the middle of the lateritic section in the hills on the west of Asota. About a mile north-by-west of Bhátia, the dark-red ferruginous rock presents the appearance of a porphyry, as it contains a white steatitic, or kaolinic mineral, in the form of decomposed crystals, scattered through the mass.

Thickness.

It is evident that the lateritic formation must have been subjected to a considerable amount of denudation, prior to the deposition of the sedimentary tertiary beds in Káthiáwár; for its average thickness does not probably exceed 50 feet, while there are places where such extremes as 200—250 feet are reached.

Volcanic origin.

The material of the rocks of this formation has undergone so much change, by decomposition and 'lateritization' (if I may be allowed the term), that its original aspect, or primary condition, has ever been a subject of conjecture and speculation; but there appears good evidence, in the character of some of the Káthiáwár rock, that the original material was mostly volcanic ejectamenta, and that the group represents an eruption subsequent to, and differing in many respects from, the trap out-flows.

*Gáj beds.*—The post-trappean formations occupy the margin, or border land, of the trappean area in the southern half of the province, having the coast line for its outer boundary. This belt of country averages about seven miles in breadth. No Gáj, or other tertiary, beds occur along

the southern shore of the Gulf of Cutch east of the lateritic rocks in the vicinity of Asota.

Position.

The rocks of the present group are, however, only found in portions of the marginal belt, being exposed at intervals in the south-eastern part of the field, while the largest spread of Gáj rocks occupies the boundary country between Hálár and Oká-Mandal. Within this latter area the beds are readily recognised by their fossils, which in places are very numerous.

Thickness.

The beds everywhere are so nearly horizontal, that any continuous vertical succession cannot be expected in so flat a country: scarcely any individual section can show more than 40 or 50 feet of strata, while the aggregate thickness of the Gáj beds alone must amount to several hundred feet.

South-eastern area.

In the south-eastern part of the field, rocks of tertiary age are only met with very sparingly. There are a few isolated outcrops along the margin of the traps and laterites, and some inliers in the alluvium, mostly too small to be marked on the map accompanying this paper; besides a rather large spread in the Gogha district, which includes the little island of Piram (Perim)—long renowned for its abundance of fossil bones and fossil wood. I have included all tertiary beds of this south-eastern area in the present (Gáj) group. They are quite unconformable to the lateritic rocks on which they rest in the northern part; while in the south, the latter are absent, and the tertiary beds are seen in places to rest directly upon the traps. The fossiliferous beds of western Káthiáwár have no place in the present area; it would appear that they are here deeply overlapped by other beds which I am disposed to regard as representing the uppermost portion of the Gáj group. Indeed, some of these beds closely resemble certain members of the Manchhar group in Sind, where, though almost entirely of fluviatile origin, it contains in a few places bands with Gâj fossils, intercalated above the base of the group. There are also other indications that there was no break in time between the two groups.[1]

[1] See Manual, Geol. Ind., pp. 342, 468, 469; and Memoirs, Vol. VII, p. 188.

No good sections.

In this south-eastern area there is no good section exposed anywhere, and the country, having a fairly rich soil, is mostly under cultivation. The streams are all shallow, with only short and well-separated outcrops of nearly horizontal marls, shales (some of which are gypsiferous), clays, and a few ferruginous conglomeratic deposits, some of which may indeed be only superficial and of more recent age. This is more particularly the case in the northern part of the area towards Bhávnagar.

Fossiliferous conglomerate near Akwára.

About a mile from Akwára on the road to Bhávnagar, in a small stream-course, a rusty conglomerate of clay pellets or galls and agates, passes down into a soft marly rock, bearing crystals of gypsum. Marine fossils are rather abundant in these beds; a number of spines of *Echinus* were collected from the weathered surface, together with fragments of *Pecten*, *Ostrea*, and a buccinoid shell resembling *Voluta jugora*, but too poorly preserved to be identified; also, a reptilian tooth, a fragment of a molar of *Mastodon*, a small encrusting coral, and bryozoa. Bored clay pebbles also occur in the conglomerate.

Similar marine fossils were also found near the village of Bhumbhli (3 miles from Gogha), at the tank to the south of the village, in cross-bedded coarse sandy, and hard calcareous grit; this rock also encloses small agates derived from the traps. The fossils include *Pecten*, *Ostrea*, spines of *Echinus*, and a shark's tooth, besides others not determined. This grit rests, with slight unconformity, upon clay shale, the base of which is not exposed.

Agatiferous conglomerate.

Further to the south, in the stream-course above Rámpur, a strong bed of ferruginous and agatiferous conglomerate, or coarse grit, rests on bluish-grey clay-shale; below which come rusty sandy grits, very similar to that at the Bhumbhli tank. They vary much in texture, even in different parts of the same bed; and contain layers of purple mottled clay.

At Kharaslia, a village between seven and eight miles to the south of Bhumbhli, the agatiferous conglomerate is seen at the little fall in the

stream on the east of the village. The upper part of the bed is hard, compact, and black in colour; while that below is of a light rusty colour, not so hard and in part a mere gravel; it is unlaminated, and towards the base becomes argillaceous. Above this bed is a compact layer of yellow calcareous sandstone, with raised markings on the surface, like annelid tracks; and in another part a laminated ferruginous sandstone varying in texture, and not persistent. Indeed, the section exhibits much irregularity in the deposition of these rocks, the individual members not being continuous throughout. Some fossil wood occurs sparingly in the agatiferous bed.

In another place farther up the same stream, the following section was observed (descending):—

1.—Dark earthy and coarse soft sandstone.

2.—Agatiferous gravelly conglomerate, with bands and irregular partings of dark ferruginous sandstone.

3.—Light-yellow, and then pale-bluish white clays.

There appears to be a considerable thickness of this clay, but it is not well exposed, being overrun by debris, and displaced by rain and weather. The clay is used by the villagers for washing purposes. No fossils were detected here.

The agatiferous bed is most conspicuous and strong on the hill ridge, two miles west of Háthab (six miles south of Gogha). It is here a hard ferruginous, red and yellow, arenaceous conglomerate, enclosing some large pebbles of quartzite and flinty agates. This rock forms the crest of the ridge, and rests upon a thick-bedded mottled yellow clay, which passes down into rusty-brown, coarse, earthy sandstone, with a few runs of agate gravel. It would appear that there is a great overlap here, for the lateritic rocks are seen shortly, in the plain below the west flank of the ridge.

Hill ridge west of Háthab.

The stream passing Bári, Hoidar, Gundi, and Háthab does not afford any clue to the succession of the beds; though it crosses from the trap area, through the lateritic zone, and traverses the whole breadth of the tertiary area to the coast, and is the largest stream in this part of the field.

Some Gáj beds are exposed in the steeply scarped coast line, about a mile and a half below the mouth of the stream just mentioned. A yellow and marly 'rag' bed is the most conspicuous; from it an inferior building stone has been extracted for the Thákor's summer-house, lately built on the high ground above the scarp. The rock is for the most part saline, and weathers rapidly on the surface into a fine powder. From this rock the following fossils were obtained :—

PELECYPODA.

*Venus*, sp.? (cast).
*Pecten*, comp. *corneus*, Sow.
*P.* sp.?
*Ostrea*, sp.? (very small).

BRYOZOA.

*Lunulites*, sp.? (abundant).

ECHINODERMATA.

*Cidaris*, spines.

In one place a close clay-shale, pale greenish in colour, is seen resting upon the marly limestone; no fossils were detected in the shale.

Coast flags at Gogha.

In the tide way along the coast at Gogha, and for some distance towards Kura, there are very fine soft silty flags and sandstones, that harden considerably on exposure to the air, when they form a fair paving, or flooring stone, and are largely used for that purpose in Bhávnagar. At Gogha itself, the sandstones are coarser and rusty brown in colour; with conglomeratic bands and layers among them, enclosing clay pebbles and ferruginous galls. These rocks have all the appearance of identity with the beds of Piram.

Piram Island.

This little island, which "is simply a reef of rock covered in part by blown sand,"[1] is situated about four miles off the coast opposite Háthab, six miles to the south of Gogha. Captain R. E. Ethersey, I.N., in a paper read before the Bombay Geographical Society in 1838, mentions that it is 1,800 yards long, and 300 to 500 yards wide, lying north-north-west and south-south-east; and

[1] Blanford: Memoirs, Geological Survey, India, Vol. VI, Part 1, p. 212.

is surrounded by an extensive rocky reef. At low-water spring tides, the channel between the Piram reef and a rocky reef towards the mainland is only 1,200 yards wide, and has the extraordinary depth of 360 feet, with a bottom of yellow clay. Sandhills line the west side, and both ends of the island: their general height is from 20 to 40 feet. The south-east side is low and sloping towards the Gulf of Cambay.

Discovery of fossils in 1836.

Dr. Falconer, in his paper in the Quarterly Journal of the Geological Society of London (Vol. I, 1845), states that the first announcement of the Piram fossils was given in a communication (to the Secretary of the Asiatic Society of Bengal), dated April 1836, and published in the May number of the Journal for that year, by Baron Carl von Hügel, in which he mentions their having been discovered by Dr. Lush.

Piram island is also mentioned by Dr. George Buist (March 1855), in the Transactions of the Bombay Geographical Society (Vol. XIII). He observes that the island, at low water, exhibits twenty times the area it presents at high water—being in the former case nine miles in length and three miles across;—and that "the bones and other petrifactions, found in such profusion thirty years before, when the place first became known to geologists, have been so largely drawn upon by travellers, that they are now (1855) very rarely to be met with *in situ*, though some baskets-full are always brought by the fishermen for sale to the travellers"; "and it is singular (he remarks) how correctly they are generally named by these simple people, who, it is to be presumed, are in this only repeating what they have been told."

If the fossils were becoming scarce in 1855, it is no wonder that goo specimens are now, 1883, rarely to be obtained.

In Captain Ethersey's paper, above cited, is given a carefully measured section of the bluff at the southern end of the island; it is as follows:—

SECTION, DESCENDING.

(*Beds horizontal.*)

| | Feet. | Inches. |
|---|---|---|
| Reddish mould mixed with stony rubbish . . . | 3 | 0 |
| 1. Yellow puddingstone . . . . . | 1 | 6 |
| 2 Sandy clay . . . . . | 1 | 0 |
| 3. Dark coloured puddingstone . . . . . | 0 | 6 |

| | Feet. | Inches. |
|---|---|---|
| 4. Sandy clay . . . . . | 4 | 0 |
| 5. Yellow puddingstone . . . . . | 1 | 0 |
| 6. Sandy clay . . . . . | 0 | 6 |
| 7. Recent sandstone . . . . . | 0 | 6 |
| 8. Sandy clay . . . . . | 8 | 0 |
| 9. Yellow puddingstone . . . . . | 1 | 2 |

The beds are roughly horizontal, and he truly observes, "None preserve an uniform thickness throughout the cliff." Number 7 of Ethersey's section is evidently a very soft recent-looking sandstone. Numbers 1, 3, 5, and 9 are sandy conglomerates, rather than 'puddingstones.'

Captain Fulljames describes[1] the order of succession, commencing from the surface, as thus:—

1. Loose sand and gravel.
2. Conglomerate, composed of sandstone, clay, and flints.
3. Yellow and whitish clay, with nodules of sandstones.
4. Conglomerate, as No. 2.
5. Calcareo-silicious sandstone, with a few fossils.
6. Conglomerate.
7. Indurated clay, more or less compact.
8. Conglomerate, being the principal ossiferous bed.

No precise measurement is given of these beds, but the thickest conglomerate is described to be about 3 feet, although, in general, they do not run more than 18 inches to 2 feet.

These sections are really of no value as indicating any regular succession of strata; the little island consisting merely of a number of conglomeratic beds, alternating with soft sandy silts and silty shales. Some of the conglomerates are very coarse, with large imbedded lumps of a yellowish, or greyish-brown sandstone; others are composed mostly of concretionary sandy nodules, often black in colour, some of them very large and assuming queer fantastic shapes.[2]

[1] Journal, Asiatic Society, Bengal, Vol V, p. 289.

[2] Mr. Blanford observes (Mem. Geol. Sur. Ind., Vol. VI, p. 374), "The conglomerates belong to two forms, very distinct in appearance, but both containing bones. The most prevalent is an extremely coarse rock, made up of rounded blocks of sandstone, varying from 3 feet in diameter downwards, but mostly not exceeding a foot, and very irregularly shaped. The sandstone is generally of fine texture, and grey or light brown in colour. This conglomerate is usually more or less nodular, and occasionally the bed appears chiefly made up of nodular concretionary pebbles, which, when weathered, strongly resemble casts of large univalve shells. The matrix of the pebbles which form the bulk of the rock is a coarse

The deposition of the conglomeratic rock is very irregular, at times presenting a tilted appearance, the effect of false bedding. I may here remark that the observations by several writers, of high dip and disturbance of the Piram beds, are a misinterpretation of the oblique and irregular nature of their deposition. As already stated, the strata are, on the whole, about horizontal. The beds vary in thickness from two feet downwards, and occasionally thin out altogether.

Some of the intermediate, or partition, beds of sandstone are but slightly coherent, being a grey finely micaceous laminated sand (hence Captain Ethersey's term 'recent sandstone'); others are more impure, muddy, and silty,—a sandy mud deposit. A few are shaly.

Position of fossil bed.

Nearly all the conglomeratic beds are, more or less, ossiferous; the higher ones less so: but it is one of the lower, and perhaps rather more ferruginous, beds that has proved so prolific in fossil wood and bones. This bed is situated considerably below the level of high water; and for more than half the year, is obscured by a thick covering of mud. During the months of April, May, and June, the fossil ground, or the south-eastern end of the reef, becomes scoured and free from mud; when the village men search for specimens at low tide, finding them washed up by the surf. The principal fossil bed cannot, therefore, be included in the section of strata quoted from Captain Ethersey's paper; as there he mentions that the lowest bed of it is washed by the high-spring tides. A considerable amount of uncertainty has hitherto existed regarding the proper position of the principal fossil-bearing band, but my observations show that it is as above stated.

The bones I saw *in situ* and otherwise, in my search over the exposed part of the reef, were few and far between; they present all the appearance of having been broken, and much worn, prior to deposition. Large

sandstone, containing small rounded fragments of agate and quartz, rarely exceeding an inch, and generally below ½ inch in diameter.

"The second principal variety is the same coarse sandstone with agate pebbles, the latter, however, being neither numerous nor conspicuous, without any of the rounded blocks of sandstone."

masses of fossilized drift-wood, many of them bored by *Teredo*, are not at all uncommon in the lower beds.

The following is a list of the fossils that have been found in the island :—

VERTEBRATA.

PROBOSCIDIA.

*Mastodon perimensis*, Falc. and Caut.
„ *pandionis*, Falc.
„ *latidens*, Clift.
*Dinotherium indicum*, Falc.

UNGULATA.

*Sus hysudricus*, Falc. and Caut.
*Bramatherium perimense*, Falc.
*Acerotherium perimense*, Falc. and Caut.
*Hyotherium*, sp.
*Hippotherium theobaldi*, Lyd.
„ *antilopinum*, Falc. and Caut.
„ ? sp. nov.
*Rhinoceros sivalensis*, Falc. and Caut.
*Camelopardalis sivalensis*, Falc. and Caut.
*Capra perimensis*, Lyd.

CROCODILIA.

*Crocodilus palustris*.
*Gharialis gangeticus*.

CHELONIA.

*Colossochelys atlas*, Falc. and Caut.
*Testudo*, sp.
*Trionyx*, sp.

PISCES.

Vertebra of Shark.

And the *Teredo*-bored wood, which is mostly endogenous.

There can be little doubt that the Piram beds are a marine, or at least estuarine formation (though the terrestrial remains indicate the near existence of land), and that they are one and the same formation as that of the Gogha mainland, in which, however, the ferruginous conglomerates are less conspicuous, and fossil bones very rare.

Coast rocks south of Gogha.

Following down the coast, we find, at Mitiwiri, a rusty brown hard gritty sandstone with vertical annelid tubes, exposed in the *nala*. In the scarp of the hill hard by, are seen about 30 feet of beds of similar rock, having woody-looking markings, with gravelly runs and coarse parts of quartz pellets well polished, and small agates; loose gravel also occurs between the harder beds. This rock probably represents the agate conglomerate mentioned before. No other rock is seen, and sand-drifts and dunes fringe the shore; but below high-water mark there is a very ferruginous raggy gritty sandstone.[1]

In the stream-course at Jhinjhka, near Dongar west of Mhowa, some masses of yellow-buff marly limestone are seen resting on soft argillaceous rock not well exposed. In the limestone an *Ostrea*, some small corals, and other minute marine organisms, were detected; and some detached masses of coral, lying about in the stream course, were evidently derived from the same rock. Among the specimens collected, the coral *Stylocænia vicaryi*, Haim., has been determined.

Fossil bed north of Jáferábád.

An outcrop of Gáj rock is again seen for some way along the bank of the stream that passes Kágwadar, at the bend, a mile and a quarter south of the village, and about 6 miles north of Jáferábád. It is a yellow marly limestone, with numerous fossils; indeed this locality proved the most productive of any in eastern Káthiáwár.

The following is a list of the fossils so far as I have been able to determine them:—

ZOANTHARIA.

*Calamophylia*?

[1] A spring of sweet water wells up through several orifices in this rock.

BRYOZOA.

*Escharia halaensis.*
*Discoflustrella vandenheckei.*

PELECYPODA.

*Venus granosa*, C. Sow.
„ sp.
*Dosinia pseudo-argus*, d'Arch. and Haim.
*Pectunculus pecten*, C. Sow.
*Pecten*, sp.
*Cardium triforme*, C. Sow.
„ sp.
*Cardita* (indet.)
*Arca kurracheensis*, d'Arch.
*Ostrea*, sp. (small).

GASTEROPODA.

*Cyprœa humerosa, var.*, C. Sow.
*Natica* (indet.)
*Pyrula?* sp.
*Fusus* (indet.)

In some shale (very sparingly exposed in the side of a small *nala* between Nátej and Umes, about 4 miles north-east of Unâ) I obtained a stunted variety of *Ostrea multicostata*, and the common *Placuna* of the Sind Gáj beds.

The next exposure of Gáj rock is an inlier, 3 or 4 miles in extent, at Wasáwar, 14 miles east of Pátan. Yellow shaly and flaggy limestones prevail, in which *Pecten corneus*, C. Sow., is very conspicuous. This *Pecten* zone was also frequently met with in the western extremity of the peninsula, in the country east of the *ran* that separates Oka Mandal from the mainland.

South-west coast.

Continuing on further round the coast, some 12 miles north-north-west of Veráwal there is a large spread of Gáj rock. It consists mostly of a yellowish close limestone, more or less argillaceous, and composed largely of fragmentary

organisms, among which any distinct or recognisable fossil can seldom be detected. At Khorása, east of Chorwar, the rock is a hard tough marly limestone, buff coloured, with numerous fragmentary fossils of bryozoa, corals, &c. A coral mass of dark close limestone was also observed in this locality.

The Gáj rocks continue, for some distance north-westerly, as an irregular fringe along the margin of the traps, with only a very narrow band of the lateritics intervening. They are broken through at the mouth of the Oját river, where the rocks have undergone much denudation; and the alluvium overlapping them has invaded the trap area for some way up the valley.

The tertiaries are nowhere exposed in the delta of the Bhádar river; nor seen again till the latitude of Porbandar is reached; where a broad spread extends for about 17 miles near the coast, to within a few miles of the Miáni creek.

The boundary lines within this area are complicated, on the one hand, by inliers of lateritic rocks, which protrude as crags and hummocks considerably above the present level of the tertiaries; and, on the other, by invading inlets of alluvium, where denudation has permitted it. Much of the ground north and north-west of Porbandar is sheeted with miliolite and other sub-recent accumulations, which along the seaboard form a succession of beds of solid rock, and it is by no means an easy matter to lay down a boundary line between these and the tertiary beds.

At Bhárwára, nine miles north of Porbandar, a yellow marly limestone contains numerous coral stalks (*Stylophora*), a few single corals, and, more sparingly, the rotund variety of *Venus cancellata;* one specimen of *Turritella vittata* was also obtained.

In the neighbourhood of Visáwár, six miles below Miáni, and at Túkra, two miles nearer Miáni, very rag-like disintegrating Gáj beds yielded the following fossils :—

CEPHALOPODA.

*Sepia*, sp. (cuttlebone).

GASTEROPODA.

*Turritella subfasciata*, d'Arch. and Haim.
„ *angulata*, C. Sow.
*Natica*, sp.
*Trochus loryi ?* d'Arch. and Haim.
„ *cumulans ?* Brong.
*Cerithium rude*, C. Sow.
*Cypræa humerosa*, C. Sow.
„ *nasuta ?* C. Sow.

PELECYPODA.

*Cucula trigonalis*.
„ sp. (comp. *fava* et *striata*).
*Dosinia pseudoargus*, d'Arch. and Haim.
*Astarte hyderabadensis*, d'Arch. and Haim.
*Venus granosa* vel *cancellata*, C. Sow.
„ *non-scripta ?* C. Sow.
*Cardium triforme*, C. Sow.
„ *picteti*, var ? d'Arch. and Haim.
„ *brongniarti ?* d'Arch.
*Pectunculus pecten*, C. Sow.
*Pecten bouei*, var. *α*, d'Arch.
„ *favrei ?* d'Arch.
*Placuna*, sp.
*Ostrea multicostata*. Desh. (fragment).

BRYOZOA.

Gen. et sp. indet.

CRUSTACEA.

*Chela* of Crab.

ECHINODERMATA.

*Echizaster*, sp.
*Cidaris* (spines).
*Clypeaster ? depressus*, C. Sow. (fragment).

POLYPES.

*Cladacora ?*
*Pachyseris murchisoni*, J. Haim.
*Trochocyathus*, sp.
*Cyclolites.*

Beyond this tract the traps come down to the sea-shore, and extend along the coast for about seven miles above the Miáni creek; thence the trap boundary trends, in a very irregular and tortuous line, northwards to the shore of the Gulf of Cutch. West of this line the whole country, including the Oka Mandal *taluk*, is covered by tertiary and higher rocks. Of these the Gáj beds prevail on the mainland, while an overlying series, possibly of later age than tertiary, occupies the greater part of Oka Mandal. There are, however, some small inliers and outcrops of Gáj rock along the eastern side of the latter area. No appreciable disturbance from the original horizontality of the beds was observed, except to the north of Gurgat and Pindára, where there is a gentle but distinct slope northwards, carrying the beds under the Gulf of Cutch.

From the outcrop in the stream bank at Pindára the following fossils were obtained:—

GASTEROPODA.

*Natica*, sp.
*Cypræa*, sp.
*Eburna*, sp.
*Turritella angulata*, C. Sow.
*Phasianella ?* comp. *oweni*, d'A. & H.

PELECYPODA.

*Dosinia pseudoargus*, d'A. & H.
*Astarte hyderabadensis*, d'A. & H.
*Venus nonscripta*, C. Sow.
*Cardium triforme*, C. Sow.
*Pecten bouei*, var. *α*, d'Arch.
„ *favrei*, d'Arch.
*Scapula ?* indet. (or *Modiola* ?).
*Pullastra virgata ?* (or *Venus subvirgata ?*).
*Placuna*, sp.
*Ostrea multicostata* (small).

ECHINODERMATA.

*Schizaster granti*, Dun. & Sla.
*Cidaris halaensis*, d'Arch. & Haim.
*Clypeaster*, sp. indet.
*Temnechinus*, sp.

Another, and more prolific fossil locality, is at an excavation for a small tank three miles east-by-north of Gága, and 4½ miles south-east of Gurgat. The following fossils were collected at this place :—

CEPHALOPODA.

*Nautilus*, sp.

GASTEROPODA.

*Natica callosa*, C. Sow.
„ sp.
*Voluta edwardsi*, var. *α*, d'Arch.
*Cassis*, sp.
*Strombus fortisi* (*?*), Brong.
*Buccinum fittoni*, d'Arch. & Haim.
*Phasianella oweni* (*?*), d'Arch. & Haim.
*Trochus cognatus*, C. Sow.
„ *cumulans*, Brong. (? young).

PELECYPODA.

*Venus non-scripta*, C. Sow.
„ *cancellata*, C. Sow.
*Cyprina transversa* (*?*), d'Arch. & Haim.
*Tellina sub-donacialis*, d'Arch. & Haim.
*Arca hybrida*, C. Sow.
„ *tortuosa*, vel. *kurracheensis*.
„ *larkhanaensis*, d'Arch.
„ sp.
*Cardium triforme*, C. Sow.
*Pectunculus pecten*, C. Sow.
*Pecten bouei*, d'Arch.
„ sp.
*Ostrea multicostata*, Desh.
*Spondylus rouaulti*, d'Arch.
*Placuna*, sp.

ECHINODERMATA.

*Schizaster granti*, Dun. and Sla.
*Euspatangus patellaris*, d'Arch.
*Clypeaster depressus*, C. Sow.
*Temnechinus costatus*, d'Arch.
„ *rousseani*, d'Arch.
*Temnechinus tuberculosus*, d'Arch. & Haim.
*Temnechinus affinis*, Dun. and Sla.
*Cidaris depressa*, Dun. and Sla.
„ *granulata*, Dun. and Sla.

POLYPES.

Several corals undetermined.

The fossil Echinoidea of the Káthiáwár collections have lately been examined and described by Professors P. Martin Duncan and W. Percy Staden.[1] Besides those enumerated in the above lists, the collection comprises a specimen of *Cœlopleurus forbesi*, d'Archiac and Haime, from near Gága; a new genus *Grammechinus* (*G. regularis*), Duncan and Sladen, from near Lowaráli, in Oka Mandal; a *Brissopsis*, sp. indet., two miles north of Visáwára, and *Breynia carinata*, d'Arch. and Haim., bringing up the total number of species to thirteen (all of miocene age), of which six are common to Cutch and Káthiáwár.

At the same locality in Oka Mandal with *Grammechinus regularis*, were found *Pecten soomrowensis*, C. Sow., *P. favrei*, d'Arch., *P.* (*Vola*) *sub-corneus*, d'Arch. and Haim., and casts of spirals.

The scarped hill ridge on the north side of the Bhogát creek mouth is formed mostly of Gáj beds; here also the above three species of *Pecten* occur, together with a small stunted variety of *Ostrea multicostata*, *Arca peethensis* (?), d'Arch., and *Dosinia pseudo-argus*, also fragments of a small crab, spines of *Cidaris*, and bryozoa, &c. Again, two miles north-west of Bhogát village, similar fossils were obtained, together with *Tellina exarata*, C. Sow., *T. subdonacialis*, a *Spondylus*, and a *Placuna*; *Trochus lorgi*, d'Arch. and Haim., *Cerithium rude*, C. Sow., *C. corrugatum*, *Ranella viperina*, d'Arch. and Haim., and *Strombus gigas*. The fossils are mostly casts, and they are frequently crowded together in parts of the rock.

Foraminifera in beds near Bhogát.

Certain of the beds exposed in a few places in the neighbourhood of Bhogát,—as, for example, a pale yellowish shaly marl in the stream bank two miles to the north-east of that village,—contain small foraminifera and other organisms, among them a *Conulites* (or *Patellina*?), which is not unlike a nummulite in shape, though differing in structure; and very probably the discovery of this foraminifer gave rise to the presumption that rocks of nummulitic age had been found in the province.

[1] Palæontologia Indica, Series XIV, Vol. 1, part 4, pp 80-91.

Coral zone.

Many masses of weathered-out coral lie scattered about the surface of the rocky ground between the villages of Nandána and Rán, indicating a coral zone not far above the local base of the group.

Several small corals were also obtained from a ferruginous bed resting immediately upon, and abutting against, the flank of one of the lateritic ridges on the north side of Nandána (near Bhatia).

In the Gáj area along the west side of the *ran* separating Oka Mandal from the mainland, a remarkably large variety of *Ostrea multicostata* occurs in soft arenaceous clays, exposed in the bank of a creek-like recess east of Lawaráli; and tubes of *Kuphus rectus* were found in the soft clay-marl of the scarp above the bank.

*Dwárka beds.*—This group comprises rocks of very various lithological character; and though the total thickness is inconsiderable, it may be possible eventually to divide the beds into sub-groups, or to mark off some of the later deposits as pleistocene. The short time at my disposal, towards the close of a long field season, did not admit of a very close examination of these rocks. They are, for the most part, unfossiliferous, though some beds are composed almost entirely of organic fragments (pounded shells, corals, &c.), but the few recognizable fossils are not sufficiently characteristic to determine the relative age of the several deposits.

Reasons for separating them from the Gáj.

The lower beds of the group are yellow, soft, and earthy, or clayey and gypseous in part; sometimes strongly stained by iron, with a few thin bands of harder rock. I have separated these beds from the Gáj group, on account of the marked change in appearance and mineral character, and the absence of any Gáj fossils; indeed, no fossils at all were obtained, except from a concretionary gritty band, in the neighbourhood of Gága, in which a small peculiar *Pecten*, unknown in the lower group, is rather abundant.

The reddish-yellow soft, earthy or marly clay beds occupy the low-lying parts of southern Oka Mandal, and extend away to the south-east, into the low hills near the coast.

Another set of beds, occupying the higher parts of southern Oka Mandal, and spreading throughout the north, consists of limestones more or less marly and arenaceous, seldom very compact, more generally porous and slightly adhering to the tongue; they occur as thick flaggy beds, some of which are made up almost entirely of small organisms (foraminifera), with the interspaces filled with crystalline matter (calcite). In colour the limestones are light and dark buff, very pale grey, pinkish yellow, ochreous, and dark yellowish-brown; the brown bed is a semi-crystalline compact rock; it occurs in the neighbourhood of Dhenki above the light-coloured beds.

Limestones variously coloured.

In Beyt Island, and along the northern coast of Oka Mandal, light-coloured marly clays, and finely arenaceous marlstones prevail; together with slightly sandy limestone, with crystalline texture; and a calcareous fine-grained sandstone.

A close pale buff limestone, more or less marly or crystalline, and rather arenaceous, extends over the surface of the country at Positra in the north-east corner of Oka Mandal, passing down into soft earthy marls. It also prevails on the higher parts southwards, to beyond Mulwásar, where the limestone is seen to rest upon a rubbly bed of nodules of marlstone in soft earthy marl, below which are soft clays and marls varying from a rich yellow to a pale-whitish colour. There are also bands of fine sandstone and sandy limestone among the lower beds. The pale buff limestone frequently contains hollow casts of some branching coral, or bryozoon, quite indeterminable, as the cavities are lined and partially filled with calcite, which has obliterated all structure.

Limestones and marls at Positra and Mulwásar.

A set of rocks, seldom met with at any great distance from the coast, and which I have tentatively included within the upper limit of the present group,—in the absence of distinct evidence to the contrary,—may, as already intimated, be eventually regarded as of post-pliocene age. These may be designated as the 'coast-fringing rocks.' They consist of porous, open, or in part

Coast-fringing rocks.

compact limestones, of pale-yellowish colour, gritty with quartz grains, and finely crystalline.

Dwárka cliffs.

These rocks form the low cliffs at Dwárka, and extend for some way along the coast; they also form an outlying ridge of hill about five miles inland from Virwála, bearing from the village of Dhrásanvel northwards through Gadechi towards the low country around Arámra, at which place the limestone is also met with at nearly sea-level. It is less porous and more sandy at this latter locality, where it has been much used for building. That of the outlying ridge is very open, from the dissolving out of the contained organic fragments; it is also false-bedded, and not uniform in texture. Occasionally a badly preserved fossil is seen; a coarsely-ribbed *Pecten*, somewhat resembling the living *P. pyxidatus* was obtained, but too much worn for distinct identification.

The cliffs at Dwárka show about 20 to 30 feet of beds varying from impure limestone to rag-stone; near the top of the section the limestone is purer, though still gritty with quartz grains, and containing shelly fragments, among which those of *Balanus* prevail. All these beds are obliquely laminated, or cross-bedded, indicating a shallow littoral sea for their deposition.

*Sub-recent and Alluvial deposits.*—Under this heading is included a variety of deposits, marine, estuarine, freshwater, and subaërial. Among the former are—the miliolite, which sheets the south-eastern margin of the peninsula, and is found in residual patches on the hills of the interior; the raised beaches and consolidated shore sands prevalent along the south-western seaboard; raised coral-reefs bordering the Gulf of Cutch; and marine concretes—with oyster beds now far from the sea,—that extend beneath the alluvial soil almost throughout the northern plains, and are exposed along the margin of the Ran of Cutch.

Sand dunes.

Among the æolian, or subaërial accumulations, the sand dunes, bordering the Ran, and in many places along the sea-margin, take precedence: while desert sand occurs on some of the plains in the northern part of Káthiáwár.

Ordinary alluvial plains prevail along the eastern limit of the province, and extend into the basin of the Sábarmati river.

It will be seen, by a reference to the map, that the belt of alluvium, which commences at Gopnáth Point near Dáta, is continuous westwards round the coast, gradually widening in the southern part, but becoming somewhat contracted in the neighbourhood of Charwar. Shortly beyond this, it expands into extensive plains and low *ran*-like flats of saline waste ground, up to the latitude of Porbandar. Thence the belt is no longer persistent; there being only a narrow strip of sub-recent deposits along the coast, with occasional inlets of low flood-land and marshy alluvium.

Miliolite.

A large portion of the area indicated above as alluvial is occupied by miliolitic limestone.[1] This rock is a finely oolitic freestone, almost free from sand or other foreign particles; the nuclei of the oolite grains are mostly organic. The minute foraminifer of each grain, though not apparent in the crude state, may be readily detected with a lens after treatment with dilute acid. The rock is thin-bedded, with strong oblique lamination. The farther it occurs from the coast, the purer is the limestone; whilst that along the seaboard is not unfrequently mixed with much sand.

Miliolite forms the bluffs and cliffs on the south-eastern coast, and extends some way inland, sheeting the surface of the country. In many places it overlaps the tertiary rocks, and is seen to rest upon the laterite and trap. In the eastern part of the alluvial area, it is seen only near the coast; while, to the westward, the whole country is encrusted with the rock. The streams in this ground have cut through it, forming small 'cañons' that are often impassable for many miles.

The cliffs of Diu island are 50 feet high, and there are quarries in the interior equally deep, which have not pierced through this peculiar rock. At Jáferábád the cliffs rise to 100 feet, and again at Gopnáth they cannot be much less, but the section at the two latter localities is not made up entirely of the limestone. There are light-grey calcareous sandstones,

[1] I have indicated the presence of the miliolite by fine transverse blue lines on the map.

indifferently cemented, associated with the miliolite, and passing the one into the other. At Gopnáth, some of the beds in the section are earthy and rubbly, being in part largely made up of nodular concretions. In some of these impure miliolitic beds, a few fresh-water shells have been found from time to time; the following five species of existing land shells were noted by Mr. Theobald in 1858,—*Bulimus insularis*, *B. punctatus*, two *Helices*, and a *Cyclotus*.

Land shells in the miliolite.

It is not unreasonable to expect that such light shells would be floated down by small streams or floods, and become entombed in a marine littoral deposit, which this evidently is.

At Mota Kotra, on the coast south of Dáta, there are overhanging cliffs in which a mass of grey softish calcareous sandstone is seen resting upon miliolite limestone, and having a similar limestone above it. The grey sandstone, though unbedded, is laminated obliquely in various directions, after the manner of blown sand; and it seems probable that much of the grey slightly coherent sandstone consisted of blown sand, in the form of dunes that became submerged; and the sand partially cemented by percolation of lime from the miliolite beds.

Blown sand interstratified.

The subrecent rocks all along this part of the coast, from Gopnáth downwards, are similarly constituted. The cliffs at Gadhara, south of Mowa, which are about 70 feet in height, well exemplify the irregular mode of their accumulation.

Along the south-west coast in the neighbourhood of Pátan Veráwal and Mangrol, the sub-recent sandy beds are stronger, and represent a littoral accumulation, or raised beach; for, at one place, I obtained many well-fossilized shells, such as *Conus*, *Cypræa*, and several Pelecypoda. The harder portions of this rock, not always on the same horizon, have been largely quarried for an inferior building stone, while other portions of it are still incoherent. The upper part, which contains the shells, is coarse-grained and softish.

Raised beach on south-west coast.

Miliolite used for Veráwal break-water.

At Veráwal a variety of miliolite is quarried, in enormous masses, for the break-water. It is a fine-grained close white rock, though much honeycombed, averaging about three feet in thickness. It rests, with an earthy parting, upon a darker and more compact, though much worn and perforated, limestone, which passes down into a concretionary, impure sandy limestone; this latter is, in part, a mass of nodular concretions. In another quarry near by, a compact, whitish, finely-speckled miliolitic limestone was observed to pass laterally into an open porous sandy-looking rock—though made up very largely of organic fragments and minute organisms—which much resembles the raised shore rock mentioned above.

The miliolite of the interior occurs capriciously in the gorges of the hills, or as patches on their sides, like remnants of a snow drift; and, though conspicuous enough in the field, these restricted patches could not be indicated except on a large-scale map. The rock is extensively used both as a building stone and for making lime.

Miliolite on Chotila hill.

The conical hill of Chotila, that gives its name to the *thána* and large village on the high road mid-way between Wadhwán and Rájkot, is the highest point in all northern Káthiáwár. It is recorded as being 1,173 feet above mean sea-level, and is about 550 feet higher than the surrounding plains. The hill is of trap, with a nether foundation of sandstone, as described in a previous page; but in the fringe of miliolite which occurs around its truncated top, there is conclusive evidence that this hill, and consequently all the surrounding country, has been beneath the sea within comparatively recent times. Probably the greater part of the peninsula was depressed at least 1,170 feet lower than it stands at the present day.

Rock plains.

Extensive rock plains are a peculiar feature in the western parts of Káthiáwár, more particularly in the Dhrol and the Nawánagar States. The rock of these parts is bedded trap, mostly decomposed and crumbling. Yet the surface of the country is almost as level as that of an alluvial plain. The planing down of such material could not have been effected by subaërial denu-

dation, and, I conclude, could only have been produced by a gradually encroaching sea,—presumably the waters that have left their limit-mark in the miliolite on the hills of the interior.

The Ran.

The Ran of Cutch (or Little Ran in contradistinction to the Great Western Ran) as the low-level waste to the north of Káthiáwár is called, was doubtless, at no very distant date, a shallow gulf, or arm of the sea,—an extension of the present Gulf of Cutch, which itself is now very shallow,—and, being elevated with the general upheaval of the district, became silted up by the accumulation of mud (clays) brought there by streams from the surrounding lands.

The surface soil of the Ran is mostly a yellowish drab clay, with strong saline efflorescence, or a powdery surface, such as is seen on the '*reh*' ground of other parts of India. At the salt-works near Kúda (or Kúra) within the Dhrangadra State, and about 65 miles from the head of the Gulf of Cutch, the section in the brine pits is as follows (descending) :—

1. Surface soil of saline earthy clay.
2. '*Kholia*' (or '*Korea*'), a dark earthy plastic clay.
3. '*Soneo*' (or '*Honeo*'), a brown clunch, a close stiff clay.
4. '*Lilera,*' a dark bluish, saline plastic clay with imbedded crystals of gypsum, hollow casts of decomposed vegetable fibre (? rootlets), and many small shells.

The base of No. 4 was not reached in the brine-pits, which are about 10 or 12 feet in depth; neither was it possible to determine the thickness of the several beds of clay, as the wicker-work protecting the sides obscured the section.

The *soneo* clay (No. 3) is impervious to water, and almost free from salt; the brine is obtained from the bed below.[1] The following is a provi-

[1] The brine is baled out and run into 'pans,' or shallow rectangular floors, where it is allowed to concentrate by natural evaporation, when the salt crystallizes in segregated lumps, and the remaining liquor is run off. The best salt is that crystallized in half-inch cubes. The salt is stacked in large heaps, exposed to all weathers. Some of the heaps had been there for seven years, and apparently little the worse for the exposure.

sional list of the little shells from the *lilera* clay (No. 4), after a preliminary examination of them by Mr. G. Nevill (late of the Indian Museum), who has kindly taken them in hand for determination and description :—

*Tympanotomus fluviatilis.*
*Pirenella caillandi* (and *layardi ?*).
*Assiminea* (sub-gen. of *Rissoa*), sp.
A new sp. of *Rissoidæ* (*Fairbankia feddeni*, Nev.)
*Stenothyra*, two sp. (*minima*, and var. ? new sp.).
*Melampus striatus*, var. *microsculpta*, Nev.
Probably a new sp. of the rare gen. *Theora*.
*Glaucomya* (*Glauconome*), near *chinensis*.
Besides three or four others not determined.

A deserted extension of the gulf.

It will be seen that the collection, though small, is of some interest to the conchologist, as well as to the geologist. The general facies presents a mingling of brackish water with marine forms; and, in connection with the fact that the locality is situated 65 miles from the present head of the gulf, bears out the hypothesis already stated, that the Ran had been an annexe of the gulf not so very long ago, which, as the salt water receded, became silted up.

Alluvium near the Ran.

A belt of alluvium, mostly sub-aërial, extends along the northern limit of the Káthiáwár peninsula : its outer margin, forming the southern coast line of the Ran, is in many parts loaded with sand dunes (raised by the prevailing wind from W.S.W.). The belt varies in width from two or three miles at Kúda, to about sixteen miles in the Mália district; while, in the east, it widens to six or seven miles, and, sweeping round the jurassic rock area of Dhrangadra, spreads out into far-reaching plains, which extend into the Ahmedabad country.

Older alluvium.

Along the inner margin of this alluvium, there are sundry accumulations which I regard as older alluvium. They are more consolidated than the later deposits, and in many places yield a fair building stone. The surface of these older

alluvial rocks shows wear and denudation in some parts of the field, and are even occasionally heavily conglomeratic.

Coral reefs in Gulf of Cutch.

*Raised coral reefs and oyster beds.*—The whole of the sea-board facing the Gulf of Cutch from Nawánagar westward, including the islands off the coast, is fringed with dead coral reefs: the surfaces of which are much exposed at low spring tides. In some places the coral floor extends inland up to high tide level, as a Saláya, the *bandar* for the town of Khambhála. The coral has a very fine and uniform texture, and has been worked as a substitute for stone for building, but not with very satisfactory results owing to salt impregnation.

The existence of these dead coral reefs is, of course, a proof that the country has been rising during late times.

Dead oyster beds indicating upheaval.

A further instance of the rising of the peninsula is seen in the occurrence of dead oyster beds in the Mália district, some way above the head of the gulf. One of these dead oyster beds may be seen in the bed of a stream two miles north of Mália, 15 miles from the nearest sea-coast, and five miles from the highest spring-tide mark. A second locality is to the east of Mália, where the oyster bed is exposed along the banks of a small stream course near the village of Chikli. This site is 22 miles in a bee-line from the present sea-coast, and about ten miles from the highest spring-tide mark. There are at least two large species of *Ostrea*, one of which is identical with the edible oyster of the south coast. The associated rocks are sub-recent concrete imperfectly cemented, and gravel beds. Both the localities mentioned are within a mile and a half of the Ran.[1]

Soil.

The soil of the plains is very shallow; and varies from black cotton soil, where the floor is of trap, to a light sandy one when resting upon sandstone. The eastern side of any extensive spread of the latter is almost wholly of pure sand, accumulated in that direction by the prevailing westerly winds.

[1] Some marine shells, of sub-recent date, were also collected from the surface of the Ran in this locality.

## CHAPTER III.

### GENERAL SUMMARY.

The oldest rocks in the country, the Umia sandstones, cannot be placed lower in the geological scale than the uppermost division of the Gondwána system of peninsular India; they occupy a subordinate area in the northern part of the province. Upon them rest other sandstones and grits, with a meagre development of limestone; these upper beds may be regarded as the remains of a newer group than the Umias; and they probably belong to an early cretaceous age. The trappean system is next represented by a very extensive and thick series of volcanic products; which, by their extraordinary display of flow and dyke features, indicate, more especially than in any other part of India, a period of great fissure eruption.

In the latter part of the trappean period it would appear that the eruptions became more local and restricted to certain centres of issue, assimilating more to the nature of volcanoes, as illustrated in the Junágarh and the Barda hills. Some time subsequent to the fissure-eruption period the surface of the country became subject to a great amount of denudation, in some parts more than in others. In the northern division, for instance, the traps have been entirely denuded, laying bare the cretaceous and jurassic sandstones that have themselves also undergone much scouring and partial removal. About this time the lower half of the province was depressed to a certain extent, bringing the southern margin of the traps beneath the sea, and then tertiary strata of miocene age were deposited as a littoral fringe upon the submerged portion of the traps. The south-western part appears to have remained under water longer to admit of later accumulations upon the miocene rocks. After the depression a period of elevation set in; but at a later date, *i.e.*, in sub-recent times, nearly the whole province was again dipped beneath the sea—only the tops of the highest hills probably escaping submersion; and on its final elevation the receding waters left their mark in the patches and fringes of white miliolite now seen on the sides of the hills and in

recesses of the ravines. It seems probable that the Ran was deserted by the sea towards the close of this last elevation. It is not yet known that the upward movement has altogether ceased; bench-marks were, however, laid down by Captain Baird, R.E., of the Trigonometrical Survey, in 1873-75, to ascertain the rise or fall of the land; but as yet sufficient time has not elapsed for testing the change.

## CHAPTER IV.

### ECONOMIC PRODUCTS.

#### *Minerals.*

*Coal.*—As has already been stated, when treating of the Umia rocks, thin strings of coaly matter, in a band of carbonaceous shale, near Thán, north of Chotila, have given rise to frequent reports of the existence of coal in this province. I can only repeat that this deposit is not worthy of the name even of 'fuel,' as it will not support its own combustion.

*Iron.*—This metal was formerly worked to some extent in many parts of the province. At Kantrori, near Sara, in the north, there are very large refuse heaps of iron-slag, indicating a considerable industry now abandoned. The ore was doubtless obtained from the ironstone bands near the top of the Umia group.

In the west, the lateritic rocks have yielded very rich iron ore; near Bákharla, not far from Porbandar, a number of small pits, 5 to 15 feet deep, have been sunk in the laterite to obtain the ore; and, again, at Pálakra, further to the north, there is evidence of a past industry in this metal. The mines have not been worked by the present generation, and to-day there is not a furnace in the province. The scarcity of fuel, and the cheapness of the imported metal, have been the cause of the indigenous manufacture dying out.

*Magnetic iron sand.*—A black sand, used by clerks and others as a blotter, is found in two or three places on the shore south of Gopnáth Point. It consists mostly of magnetic iron derived from the traps.

*Lead and copper.*—Within the Gir hills, at a site called Bánej-nes, on the Machundri stream, that flows past Una, some galena, associated with copper pyrites, occurs very sparingly in a quartz vein in the trap rocks. The vein, which bears about north-15°-east, and south-15°-west, is only a few inches (2″ to 6″) in width where exposed, and it could not be traced for many yards, neither do the ores prevail throughout its course. I do not, therefore, consider there is any promise of a workable quantity of ore being found in the place. The uncommon occurrence (in India) of a metalliferous vein in the trap rocks is worthy of note.

*Lime.*—The miliolite, wherever procurable, is largely used for making lime. At Dhrangadra a thin portion of limy earth among the sandstones quarried for building is carefully collected and kilned, as it is the only source in that part of the district. At Múli and other places a kankary deposit at the base of the traps is used for local purposes.

*Gypsum.*—This mineral occurs in some of the tertiary beds in the Bhávnagar State, near Nandána in the western part of Halar, in the hills about Kuranga south of Oka Mandal, and one or two other places, as small tabular masses and crystals of selenite, scattered through the clays; but scarcely in sufficient quantity or purity to be of much commercial value. At Bhávnagar, however, it is kilned and used by the State Engineer for moulds and model castings.[1]

*Moss-agate.*—At Khijaria, a village 2½ miles west of Tankára, in the Morvi State, some moss-agate, occurring as a large irregular vein in decomposed amygdaloidal trap, has been worked in a desultory way, by the villagers, for a number of years. The agate is purchased by native traders from Bombay. A royalty of two rupees per *maun* is levied by the State. Amythistine quartz and clear rock-crystal are occasionally met with in the workings.

### *Building and Ornamental Stones.*

*Miliolite*, which is a finely oolitic and highly organic porous limestone, is extensively used as a building stone for Hindu temples,

[1] The tertiary beds of Cutch would yield a much greater supply of gypsum in large clear crystal and tabular masses, more especially in the western part of that State, south of Lakpat.

bridging the smaller streams, and ashlar work generally. It is a most useful stone, being readily worked: it can be faced with an axe, and the chips and rubble burnt for lime, the quality of which is said to be excellent.

This stone is exported in large quantities from the port of Porbandar to Bombay and other places, and has hence gained the well-known name of 'Porbandar stone;' the quarries, however, whence it is taken are situated along the western base of the Bárda hills, about 9 miles north-east of the port. The deposit there is very thick, and occurs in three parallel ridges; or ledges, rising one above the other; it is white-coloured and very obliquely laminated at an angle of about 22°, varying in different quarries. The miliólite extends out into the plains around Adatiána and Ránáwu.

A much inferior stone has been largely quarried at Porbandar itself, from a very open imperfectly cemented shore deposit, or raised beach; this doubtless has often been palmed off as genuine Porbandar stone. The effect of rain and weather on miliolite is to harden it and render it less porous.

*Dhrangadra stone.*—There are extensive quarries in the neighbourhood of Dhrangadra, the chief town of that State. The stone is renowned throughout, and beyond, the province: a quantity of it having even been carted as far as Bhooj in Cutch, for the Rao's new palace. It is a light-coloured open-grained slightly kaolinic sandstone, very cross-bedded, with oblique lamination; varying in texture (even in a hand specimen) from fine-grained to coarse and gritty, and in colour from white to pale pink or yellow. The stone has been employed largely in masonry at Dhrangadra: it was exclusively used in building the new court-house, the palatial gateway, with clock-tower, the school-house, &c. The finer varieties admit of rough carving for ornamental work.

Near Baoli, a village six miles south-west of Dhrangadra, a bed of sandstone of remarkably fine texture and even lamination is quarried and used as a whetstone: it is also worked for ornamental purposes, carved into platters, cups, and water-vessels, being sufficiently porous to act as

a refrigerator. Pipe-bowls, for opium-smoking, are also cut out of this stone.

*Marble.*—In 1878 it was reported to me that statuary marble 'in any quantity' had been discovered in the Gondal State, and that quarries had been opened in it. The so-called 'marble quarries' proved to be some very limited surface diggings along an irregular vein in the trap rocks, near the villages of Khírasra and Sejriála in the Bháyáwadar *pargana*, about 15 miles north-west of Dhoráji. The vein is not more than about 30 inches in width, often less; and the marble is associated with quartz and other spars, such as coarsely crystallized calcite (calc-spar) of which the vein is largely made up in places. The workable stone is a white-mottled hard marble, capable of a high polish, and consists of a mingled combination of aragonite and calcite. I do not consider it could be worked profitably for exportation, but it might be locally employed for ornamental purposes in a small way.

The stone is interesting from a mineralogical point of view: it is decidedly harder than ordinary white marble, and somewhat heavier; neither has it any distinct rhombic cleavage. Mr. Mallet has determined it to be "remarkably pure carbonate of lime, without any appreciable quantity of either iron or magnesia." Its specific gravity is 2·87 (which is higher than any calcite, and a little under ordinary aragonite). Its hardness (3·5—4) more nearly agrees with aragonite. When strongly heated, before the blow-pipe, it does not fall to pieces like aragonite, but becomes opaque and more readily friable than ordinary white marble after being similarly heated.



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